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NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY. APPENDIX R. WATE--ETC(U)
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North Atlantic Regional Water Resources Study

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Appendix R. Water Supply.

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NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE

MAY 1972

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The North Atlantic Regional Water Resources (NAR) Study examined a wide variety of water and related land resources, needs and devices in formulating a broad, coordinated program to guide future resource development and management in the North Atlantic Region. The Study was authorized by the 1965 Water Resources Planning Act (PL 89-80) and the 1965 Flood Control Act (PL 89-298), and carried out under guidelines set by the Water Resources Council.

The recommended program and alternatives developed for the North Atlantic Region were prepared under the direction of the NAR Study Coordinating Committee, a partnership of resource planners representing some 25 Federal, regional and State agencies. The NAR Study Report presents this program and the alternatives as a framework for future action based on a planning period running through 2020, with bench mark planning years of 1980 and 2000.

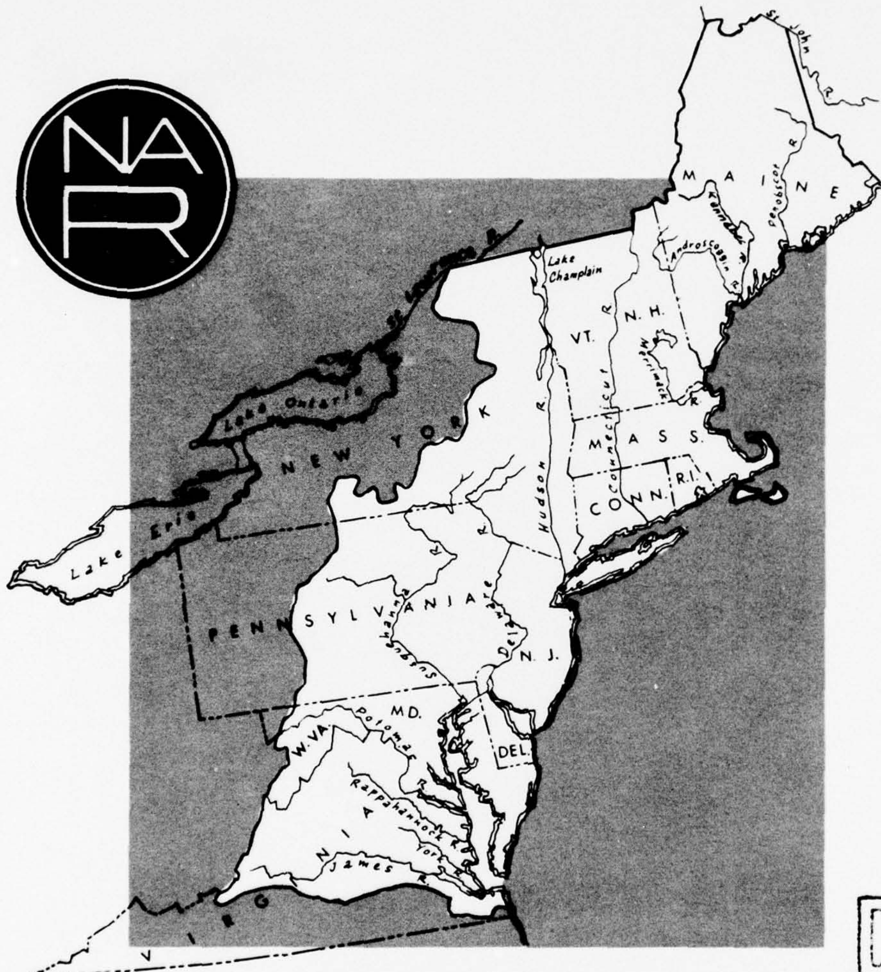
The planning partners focused on three major objectives -- National Income, Regional Development and Environmental Quality -- in developing and documenting the information which decision-makers will need for managing water and related land resources in the interest of the people of the North Atlantic Region.

In addition to the NAR Study Main Report and Annexes, there are the following 22 Appendices:

A. History of Study
B. Economic Base
C. Climate, Meteorology and Hydrology
D. Geology and Ground Water
E. Flood Damage Reduction and Water Management for Major Rivers and Coastal Areas
F. Upstream Flood Prevention and Water Management
G. Land Use and Management
H. Minerals
I. Irrigation
J. Land Drainage
K. Navigation
L. Water Quality and Pollution
M. Outdoor Recreation
N. Visual and Cultural Environment
O. Fish and Wildlife
P. Power
Q. Erosion and Sedimentation
R. Water Supply
S. Legal and Institutional Environment
T. Plan Formulation
U. Coastal and Estuarine Areas
V. Health Aspects

WATER RESOURCES NEEDS AND POTENTIALS FOR AN EXPANDING SOCIETY

Appendix R
Water Supply



Prepared by

North Atlantic Regional Water Resources Study Group
North Atlantic Division
Corps of Engineers, U.S. Army

for the

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE

SYLLABUS

While the North Atlantic Region's 41-inch average annual precipitation is more than adequate to meet both present and future water supply needs, there is a definite need for further development and management of water sources to keep abreast of the increasing demands of anticipated population growth and urban and industrial development.

The potential plight of the Region's water supply situation was brought into proper, if somewhat startling, perspective during the five-year drought that ended in 1967. Many sectors of the NAR experienced critical water supply shortages, and some 14 million people, about 28% of the Region's population, were subjected to water-use restrictions.

That drought is now history, but it provided a stark reminder that the NAR's water supplies are barely adequate to meet present needs under traditional unlimited or unrestrained use patterns. The urgency of this situation is magnified when we look into the future. The population of the Region, approximately 50 million, is growing and projected to double by 2020. While the population increases, individual use of water is also increasing.

The analysis in this Appendix has been divided into two major categories: public water supply, including all water supplied from central systems, both public and private; and industrial water supply, which includes all water used by the manufacturing industries in the Region. Summaries of the rural water supply situation and an up-to-date examination of developing desalting technologies are also included in the Appendix as separate chapters.

Future water supply requirements have been developed for the two NAR Study bench mark years--1980 and 2000, and for 2020, the Study target year. These projected requirements were estimated at each year for the three Study objectives--Regional Development (RD), National Efficiency (NE) and Environmental Quality (EQ).

The material in this Appendix has been developed for use in the formulation of the mixed-objective programs for each of the 21 NAR Areas. Data on projected withdrawal needs will be integrated into the NAR Supply Model analysis of the resource necessary to meet instream mixed-objective withdrawal and requirements for all purposes.

The Region's present public water supply needs of 5,523 million gallons per day (m.g.d.), are projected to increase by 2020 to 13,106 m.g.d. under the EQ objective, 15,664 m.g.d. under the NE objective and 16,058 m.g.d. under the RD objective.

Additional facilities to satisfy projected future public water supply requirements, over the entire Study period, are estimated to cost $3.5 billion under the EQ objective, $4.7 billion under the NE objective, and $5.5 billion under the RD objective. Proposed devices include storage, increased treatment plant and intake and pumping capacities, diversions and development of ground water. Increased treatment plant facilities represent soem 60% of the total costs, and additional storage capacity of aobut 2.3 million acre-feet (EQ), 3.3 million acre-feet (NE), and 3.5 million acre-feet (RD), represent approximately 25% of the costs.

Self-supplied industrial water withdrawal are expected to increase from the present value of 6,701 m.g.d. to 2020 requirements of 32,005 m.g.d. (EQ), 36,025 m.g.d. (NE) and 39,911 m.g.d. (RD). These figures do not include publicly-supplied fresh water withdrawals for industrial use which are included under public water supply. Self-supplied fresh water accounts for about 54% of the above figures with the remainder primarily brackish water with some waste water.

Meeting self-supplied industrial water requirements would involve estimated costs of about $240 million dollars under the EQ objective, $262 million under the NE objective, and $287 million under the RD objective. Proposed devices include additional fresh water and brackish water intake and pumping capacities, ground water development and increased use of waste water.

The water to meet the growing needs of the expanding NAR is available. However, the water sources must be conserved and the resources harvested to allow for the availability of water when it is needed and where it is needed, and in sufficient quantities and quality.

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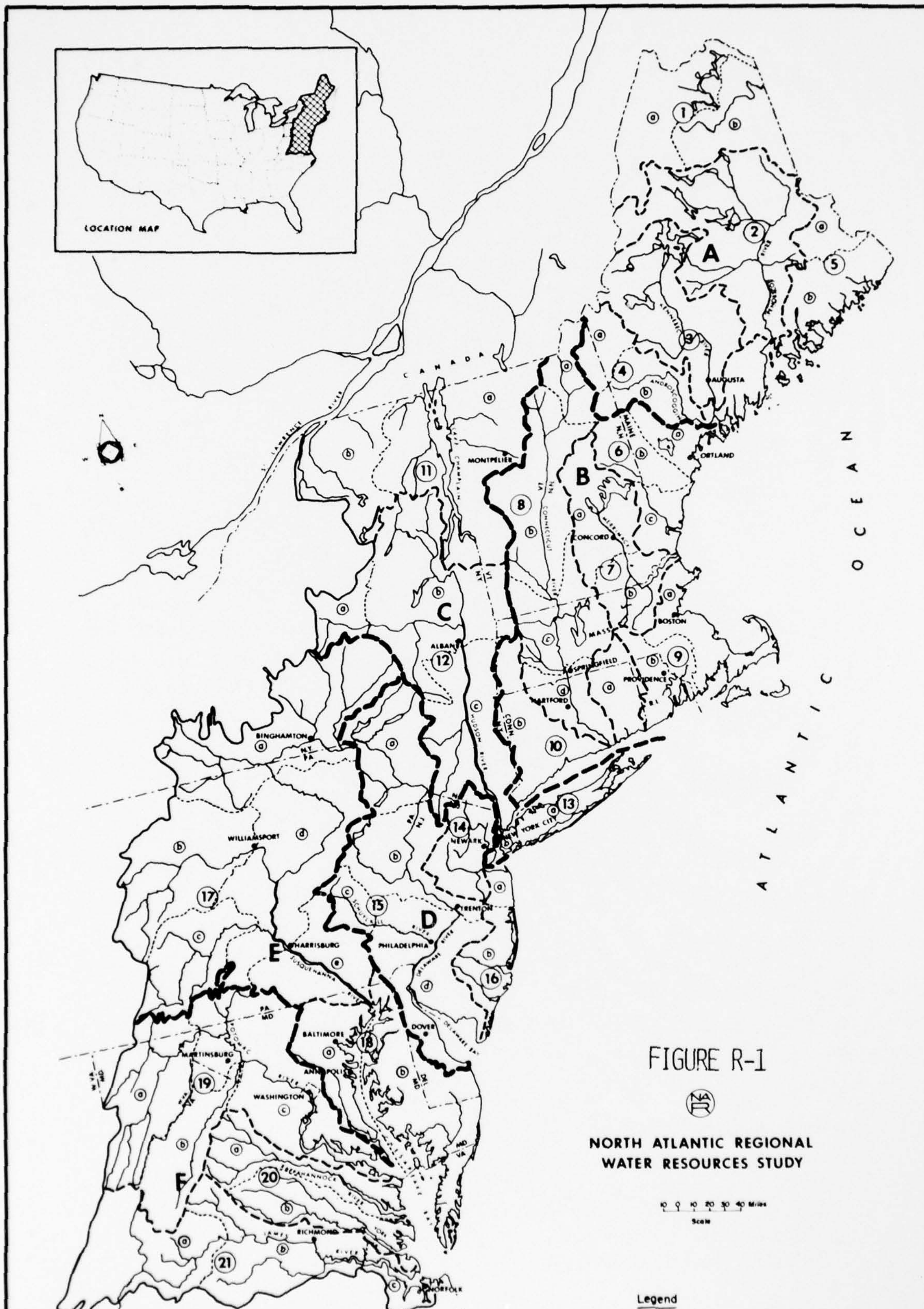

LOCATION MAP
CANADA
ATLANTIC OCEAN
FIGURE R-1
NORTH ATLANTIC REGIONAL
WATER RESOURCES STUDY
Scale
Legend
Sub-region boundary
Basin or area boundary
Working sub-area boundary for plan formulation
AUGUSTA
PORTLAND
MONTPELIER
CONCORD
BOSTON
ALBANY
SPRINGFIELD
PROVIDENCE
HARTFORD
BINGHAMTON
WILLIAMSPORT
NEWARK
NEW YORK CITY
TRENTON
HARRISBURG
PHILADELPHIA
DOVER
BALTIMORE
ANNAPOLIS
MARTINSBURG
WASHINGTON
RICHMOND
NORFOLK

CHAPTER 1. INTRODUCTION

Appendix R contains the methodology and data on water supply, both present and future, that was an input into the plan formulation process of the North Atlantic Regional Water Resources (N.A.R.) Study. The Study will provide a broad comprehensive framework analysis of the water and related land resources of the Region through the year 2020 to be used in determining how these resources can best be utilized.

This appendix should not be construed to contain a plan for water supply. Water supply is an integral and indivisible part of multiple purpose water management and the plans for water supply are part of the area plans presented in Annex 1 of the Report.

Desalting of seawater and brackish water for water supply is an advancing technology. Therefore, a report entitled "Desalting as a Water Supply Source" was prepared by the staff of the U.S. Department of the Interior's Office of Saline Water for the North Atlantic Regional Water Resources Study Coordinating Committee and is included in this Appendix as Chapter 6.

The NAR Supply Model and the mixed objective plan for multiple-purpose use of the Region's water resources, considers desalting as one of the ways that water can be supplied.

However, in the methodology developed in this Appendix, single-purpose water supply development is guided by extrapolation from existing practice and includes no desalting.

The requirements for rural water supply, including rural domestic and livestock needs, presented in Chapter 5 were developed by the U.S. Department of Agriculture.

PURPOSE AND SCOPE

PURPOSE

The purpose of this Appendix ~~R~~ is to present data on existing public and industrial water supply use in the North Atlantic Region, to estimate the Region's future water supply needs and requirements for the various study objectives, and to develop the extent and cost of additional facilities and programs necessary to satisfy these needs. While this Appendix presents water supply from a single-purpose viewpoint, it is also intended for use in the development of the needs for the NAR mixed objective framework program and in supplementing related cost and resource allocation analyses.

next page

cont

SCOPE

This Appendix presents the existing average daily public and industrial water supply in the North Atlantic Region as determined from available data. The future requirements were based on projection of population and economic information and are presented as average daily requirements. The extent of existing facilities that presently furnish water was obtained from available data. General determinations were made as to the facilities and programs that would be required to satisfy future needs, and their costs. This data is categorized by the three NAR Study objectives, Environmental Quality, National Efficiency and Regional Development under the Study's three bench mark years, 1980, 2000 and 2020, for the Region's 21 hydrologic Areas.

STUDY RELATIONSHIP

The future water supply requirements as developed in this Appendix will form an essential part of plan formulation, and will also serve as input to Appendix L, Water Quality and Pollution. Information from Appendix B, Economic Base; Appendix C, Climate, Meteorology and Hydrology, and Appendix D, Geology and Ground Water, were used in the preparation of Appendix R. Water use in the Mineral Industry is shown in Appendix H, Minerals.

CHAPTER 2. METHODOLOGY

PUBLIC WATER

PRESENT USE

For the purposes of the NAR Study, 1965 is considered to be the base year, or present conditions, for public water supply. An inventory of all public water supply systems in the Northeastern United States was prepared for the Northeastern United States Water Supply Study, which is currently being conducted by the North Atlantic Division of the Corps of Engineers. This inventory provided the basic data for present public water use and included the following information: name of the utility, ownership (private or public), county location, water source (ground or surface), annual water production and population served. The above information has been aggregated by state and by county in the inventory.

FUTURE USE

Population and Population Served

Population projections for all the counties in the NAR for the years 1980, 2000 and 2020 were estimated using the Office of Business Economics projections in Appendix B, Economic Base, as control totals. The population figures for 1965 were straight-line interpolated between the 1960 and 1980 figures. The proportion of the total population served in the base year by central water systems was determined, and estimates were then made for the population served in each county for the three bench mark years. It was assumed for these estimates that the percentage served would rise during the life of the study, due in part to the anticipated increase in urbanization and suburban expansion throughout the NAR, coupled with the desire of the public for the greater degree of reliability for water supply offered by central water systems.

These estimates were made by a member of the NAR Study engineering staff and were reviewed by the NAR economics staff. The percentage of the population served ranged from as low as 3% to 4% for the base year in some of the rural counties in the southern portion of the Study area, with an anticipated increase to about 10% to 15% by the year 2020, to a high of 100% for several of the highly urbanized counties. For the entire NAR, approximately 88% of the total population in 1965 was served by central water systems. This percentage is expected to increase to 92% by the year 2020.

Projected Public Water Requirements

The development of the projected public water supply requirements was accomplished in two steps -- first, the standard method of

applying per capita water use to future population; and then the utilization of a mathematical model.

At the Study's inception, before the development of the NAR Demand Model, the standard approach was used to estimate the future public water supply. Subsequent to the completion of the demand model, it was decided that the versatility of the model would be better suited to the framework concept of the Study. The populations and populations served developed for the standard approach were retained for use in the model. The estimated future public water supply figures presented in this Appendix were developed from the model.

Standard Approach. A variation of the standard approach to public water supply projections was made for the NAR Study. Public water supply can be divided into the following four basic categories: domestic, commercial, municipal and industrial. The first three are interrelated, in that their use is influenced by the same factors, such as population and income. Industrial water use, however is affected primarily by output, employment and technology. It was therefore considered that the portion of the public supply that is furnished to industry should be treated separately.

Accordingly, when Cornell University prepared a report under contract on industrial water use in the NAR, it was requested that as part of that study, a breakdown be prepared to show what portion of the total industrial water use was from public supply. The Cornell Study is discussed in greater detail on page R-14 of this chapter. This was done for every area in the NAR for the base year and for the three bench mark years using county data which was aggregated into basinwide totals.

The present non-industrial water use for 1965 was estimated by subtracting the publicly-supplied industrial water use from the total public water use. Per capita use figures for 1965 were determined by dividing the non-industrial public use by the population served. The projected per capita water uses for the years 1980, 2000 and 2020 were determined from a series of curves developed for the Ohio River Basin Framework Study, which are shown in Figure R-2. These curves are based on observed cross-sectional increases in consumption from small towns to cities, and their use entails the assumption that the cross-sectional information is appropriate to our time series projections. The county per capita use estimates derived for the bench mark years were applied to the estimated populations served in each county to obtain the non-industrial public water use. To these estimates were added the projections for the publicly-supplied industrial water use in the bench mark years to obtain the total publicly-supplied water requirement for each county. These were then aggregated by the 21 Areas of the NAR.

Where the estimates of publicly-supplied industrial water for 1965 appeared unrealistic (e.g., exceeding total use, or where otherwise considered excessive), the method outlined above required

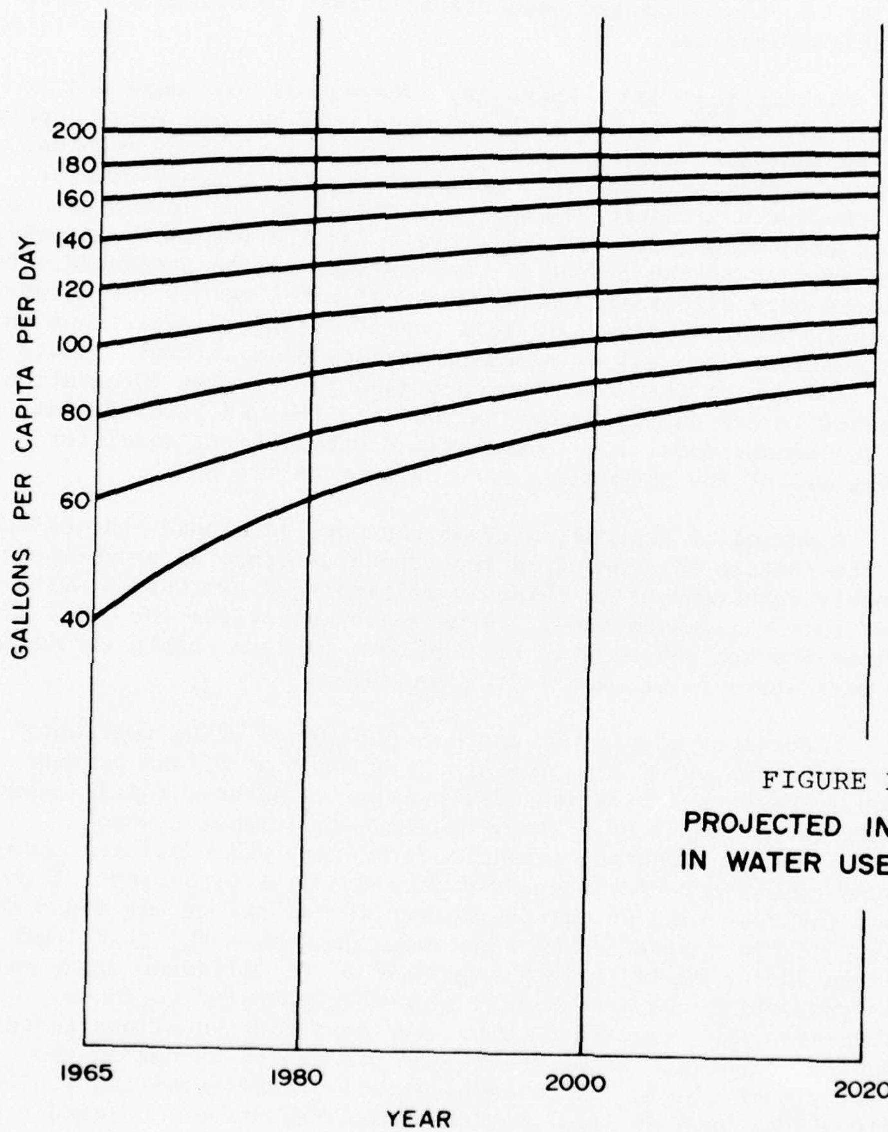


FIGURE R-2

PROJECTED INCREASE IN WATER USE (GPCD)

modification. This occurred in roughly 12% of the counties in the NAR, mostly in the southern portion. The methodology was modified as follows: the total use in 1965 was divided by the population served to obtain a per capita use figure, and the Ohio River Framework Study curves were used to develop projected per capita figures, which were then applied to the estimated populations served to obtain the projected public water use.

Mathematical Model Approach. The method just outlined is essentially a traditional one that has been used by most water supply planners in the past, and, in general, yields satisfactory results. It has certain drawbacks however, particularly for a study area as large as the North Atlantic Region. Any change in the assumptions of population projections or per capita usage for the future would make the determination of the effect of such changes on the projected water requirements very difficult. A mathematical model method for determining public water supply would lend itself easily to variations in basic assumptions, as well as permit a variety of sensitivity tests to be made. The use of the model approach also permits the integration of the public water supply determination into the NAR Study Demand Model. The demand model is a computerized mathematical model for estimating all of the withdrawal requirements of the NAR.

A series of regression equations were developed and tested against the results obtained from the standard method of projecting water supply requirements to obtain a mathematical expression which would fit into the demand model. Time series data from the State of Connecticut for the period 1929 to 1966 were used to obtain estimates for the parameters to be used in the equations.

A total of nine equations were developed using regression analysis where the water requirement was a function of one or more variables. These variables included population served, total income, per capita income and time. The standard method results were considered to be the control projections against which all the equations were compared to see which one gave the best fit. Four of the equations included time as one of the variables, and it was found that the time variable dominated the regression in such a way that there was very little variation in the projections for the different areas and that the projections were extremely high when compared to those derived through the standard method. The next four equations tested used population served, total income and per capita income as the variables, either singly, or in combination. These equations yielded projections that were at great variance with the standard method projections, ranging as high as several thousand percent in difference, with very few Areas within 100%. The final equation, which was adopted for use in the demand model, involved only population served and per capita income and produced the following comparisons -- for 1980, 91% of the 21 Areas were within 15%, and for 2020, 62% were within 15%. The decline in comparability is to be expected the further along in time that projections are made. The difference in all three years for

the entire NAR was 2% or less. The form of the equation used in the model is:

$$Q = K(P)^{.825} (Y)^{.308}$$

Q = Public water requirement in million gallons per day (m.g.d.)
P = Population served in 1000's
Y = Per capita income in dollars
K = Constant which varies for each Area and is determined by conditions in the base year

The above equation projects total public water supply requirements which include domestic, commercial, municipal and publicly-supplied industrial water. It is important to recognize that this equation represents a curve fitted to observe data. Thus it is only representative of reality as long the trends observed in the data continue generally in the same direction. The urban areas where population and income is static or on downtrend, none of those are in the NAR, this equation is not likely to be useful. The demand model, which projects the total withdrawals for the various industrial, commercial and municipal uses, estimates the part of the total use that can be expected to be furnished from public water supplies. This quantity, subtracted from the total public supply, results in the domestic water use. The domestic water use figures are examined for reasonableness in the model by dividing by the population served to obtain a per capita use figure. In several highly industrialized rural Areas, the per capita use figure developed in this manner is unreasonably low. In these rural Areas, a figure of 50 gallons per capita day is considered to be good average. Consequently, whenever the per capita use falls below 50, the model automatically assigns a value of 49 gallons per capita day to be applied to the population served to obtain domestic water use. The value of 49 is used instead of 50 so as not to affect the operation of the model. The total public water use is then the sum of the revised domestic use and the other public water uses. This procedure has been instituted to try to avoid unreasonable results which sometimes can occur when an empirical formula is used.

Alternative Objectives

Another advantage that the model technique offers is the capability to project water supply requirements for the different Study objectives. This is done by altering or modifying the variables in such a way as to reflect the specific objective being considered.

National Efficiency. The population projections and per capita incomes published in Appendix B, Economic Base, were used in the model for the National Efficiency objective to determine the projected public water supply requirements. This objective is concerned with middle value estimates of the various GNP determinants, including animal growth rates of 1.3% for population and 3.0% for productivity. The population served percentages developed under the standard

percentages developed under the standard method were retained.

Environmental Quality. It was assumed for this objective that the economic productivity and population in the Region would be lower than under the National Efficiency objective. Consequently, a lower population projection series (1.0% annual growth rate) was selected from Appendix B. The population served percentages as previously developed were held constant. This lower population series was used to determine new lower gross national and regional products. Revised personal income and per capita income were then developed from the lowered gross regional product. These lower total population, population served and per capita income figures were used in the model to determine the public water supply projections for the Environmental Quality objective.

Regional Development. The assumptions made for this objective were that the productivity in the Region would increase, but that the population would remain the same as that for the National Efficiency objective. A higher level of productivity (3.2% annual growth in product per man-hour) was selected from Appendix B to determine the higher gross national and regional products, which in turn led to the development of new personal income and per capita income values. The population served figures from the National Efficiency objective and the higher per capita income figures were used in the model to determine the public water supply projections for the Regional Development objective.

DEVICES AND COSTS

Devices

Public water supply needs can be satisfied in two ways. Additional sources can be developed or the demand can be curtailed. In the past basically only the first method was used. Demand restrictions were only used as temporary expediencies, were usually severely critized and in general had little long term effects. Therefore little information is available as to the methods that could be used to reduce demand and to the direct and indirect costs of these methods. Nevertheless it has become time that the constant growth of water demand must be checked. Pricing, re-use, rationing, education for conservation, changes in building codes and growth restrictions are some of the means available to accomplish this. The effectiveness and acceptability of these methods of restricting public water supply demands on a systematic and long term basis is not known and has not been tested in this country. For this appendix, therefore, devices were selected and their costs estimated that could provide for the needs as projected. Demand reduction below the projected amounts would reduce the need for additional sources and reduce cost for each target year.

The initial determination of the devices was done in conjunction with the standard approach for developing future public water supply needs on a county basis. Existing water use in each county was

broken down into surface-supplied and ground water-supplied, utilizing the information contained in the inventory of public water supply systems. The ground water needs will be supplied from wells (See Appendix D, Geology and Ground Water). The devices for that portion of the public water supply to be developed from surface sources combining reservoirs, pumping stations, interbasin transfers and treatment plants are covered in the Area Summaries.

Existing surface water facilities were obtained from the "1963 Inventory of Municipal Water Facilities," published by the U.S. Department of Health, Education and Welfare. This publication lists the source of supply, safe yield and treatment plant capacity of most of the central water supply systems in the Region.

Initially, two broad assumptions were made: (1.) the present ratio of surface water to ground water in each county would remain constant throughout the Study period; and (2.) the ratio of present water use of any public system to the total public water use in the county where the system is located would remain constant and would be applied to the projected public water needs of the county to determine the future requirements of that system.

Comparison of the future requirements of each supply system with the capacity of its existing facilities determined the additional devices which would be needed, as well as fixing the time frame when they would be required.

When available from reports or studies, information developed for specific water supply systems was utilized in the determination of devices and costs.

Water treatment plants and pumping stations were sized for each bench mark year. Where additional storage was indicated, it was sized to provide sufficient yield for the entire Study period. Determinations of yield were based on yield-storage relationships developed in Appendix C, using synthetically generated streamflows and a shortage index of 0.01.

Shortage index is a risk criterion that is proportional to the number of annual shortages and the square of the shortage quantities. An index of 0.01 would be equivalent to various combinations in 100 years, such as one 10% shortage, two 7% shortages, or one 7% and three 4.5% shortages. Additional information on this methodology is contained in Appendix C. Comparison of yield information from other studies with Appendix C data indicated that differences were not significant enough to be considered in the analyses of this Appendix. See Appendix T for the supply model analysis of the mixed objective plan in which consistent yield data for the Region are utilized.

Devices that could satisfy projected needs were aggregated by the 21 Areas.

Public water supply needs developed by the mathematical model are the needs that are presented in the Area Summaries. These needs vary slightly from those obtained from the standard method which were used to determine the size and quantity of the specific water supply devices that could meet the future requirements. In order to adjust the devices to match the final needs from the model, it was assumed that the ratio of the final needs to the original needs applied to the original devices would yield results that would be sufficiently accurate for a framework study. Water source development devices such as reservoirs, groundwater developments, diversions or desalting while estimated here were not used in developing the comprehensive mixed objective plan. There they were determined by the supply model (see Appendix T) as multiple purpose features and existing and estimated development constraints could be considered in the model.

Costs

The information used to obtain the costs of the various devices proposed was obtained from existing cost data and adapted for use in this Appendix. The supply model for the NAR, which concerns itself with the analysis of resource allocation and related costs for the mixed objective framework plan, utilizes cost data which are more general than those used for this Appendix. All costs presented in this Appendix have been adjusted to 1970 price levels.

As in the case of devices, where information was available from reports or studies it was utilized.

Storage. Average cost curves for reservoir storage were adapted from information developed by the New England Division, Corps of Engineers, for larger projects, and the U.S. Department of Agriculture for upstream projects. Because of the great differences in project size covered by the two sets of cost data it was necessary to develop cost information which could be utilized for the NAR Study. The curves developed for the NAR's six Sub-Regions are shown on Figure R-3 and reflect updating to 1970 cost levels.

Water Treatment Plants. A cost curve for water treatment plants, indicating total costs versus plant capacity was developed from cost information obtained from The Journal of the American Water Works Association, Engineering News-Record, and cost data developed by the New England Division, Corps of Engineers, and private engineering consultants. The costs were brought up to the 1970 level and the curve is shown on Figure R-4.

Pumping Stations. The factors that influence the cost of pumping stations, such as site conditions, pumping head and intake structure requirements, are so variable that developing specific cost curves would not be practicable. It was felt that a cost relationship such as $5,400/m.g.d. of required pumping would be adequate and would yield results compatible with framework study needs.

The $5,400/m.g.d. relationship was developed in the following manner:

First, a list of existing river pumping stations in the Delaware River Basin was compiled from information furnished by the Delaware River Basin Commission. Only the capacities of these stations was furnished.

Then, in order to determine the horsepower requirements, an arbitrary pumping head of 30 feet was assigned to each station.

Costs curves of $/Horsepower, prepared by the New England Division, Corps of Engineers, were used to determine the costs of each pumping station. The dollar costs included the structure and the pumping equipment. These pumping station cost curves are shown in Figure R-5.

Finally, the costs were totalled and divided by the total pumping capacity to obtain the $5,400/m.g.d. figure. This relationship was used to determine pumping costs for the 21 areas in the NAR.

Ground Water. Ground water costs were based on cost information contained in Appendix D, Geology and Ground Water.

Diversion. Diversion costs were obtained by assuming the locations of the point of diversion and the point of delivery, and estimating the costs of the pipelines and pumping stations needed to accomplish the deliversion. Whenever possible, existing information was utilized. Other costs which might be imposed on the basin which serves as the source of supply such as diminished fishery resources, high waste water treatment costs, reduced economic development opportunities and environmental amenities were not taken into account with inter-basin diversions examined in this study. Therefore, stated diversion costs should be treated as the minimum level of investment required and not reflective of a comprehensive evaluation of all costs associated with diversions.

Desalting. Costs of desalting are discussed in Chapter 6 of this appendix and are shown in Figures R-34 and R-35.

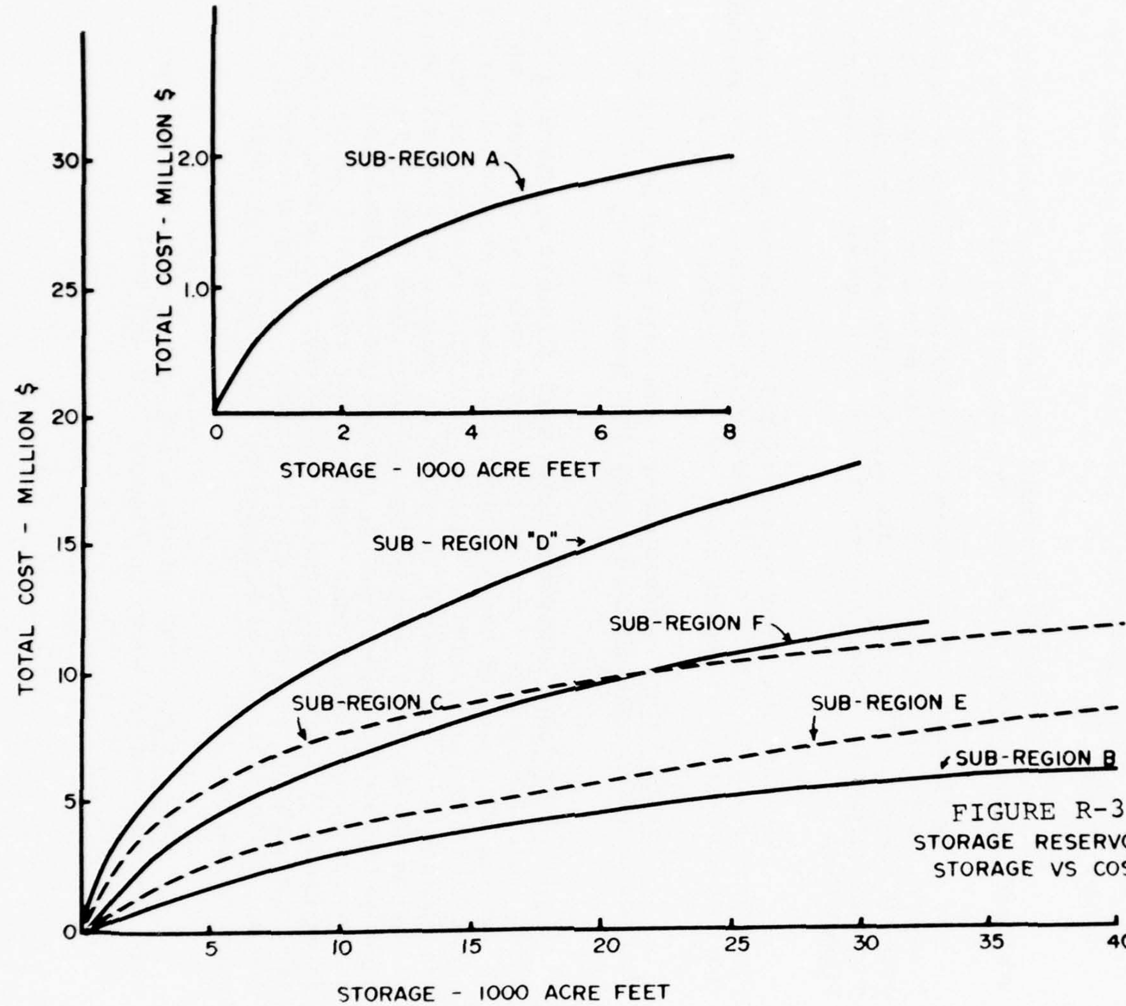


FIGURE R-3
STORAGE RESERVOIRS
STORAGE VS COST

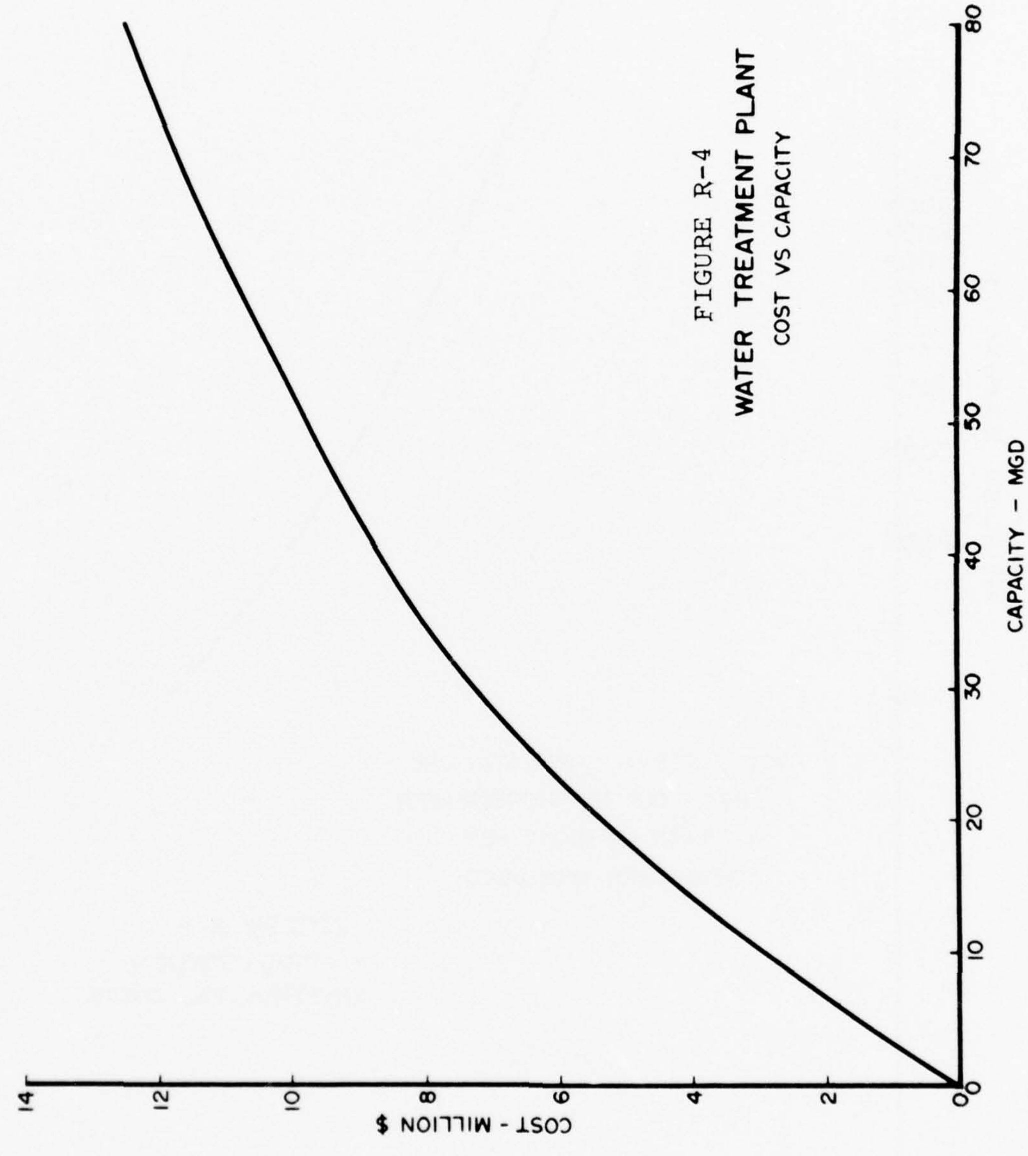
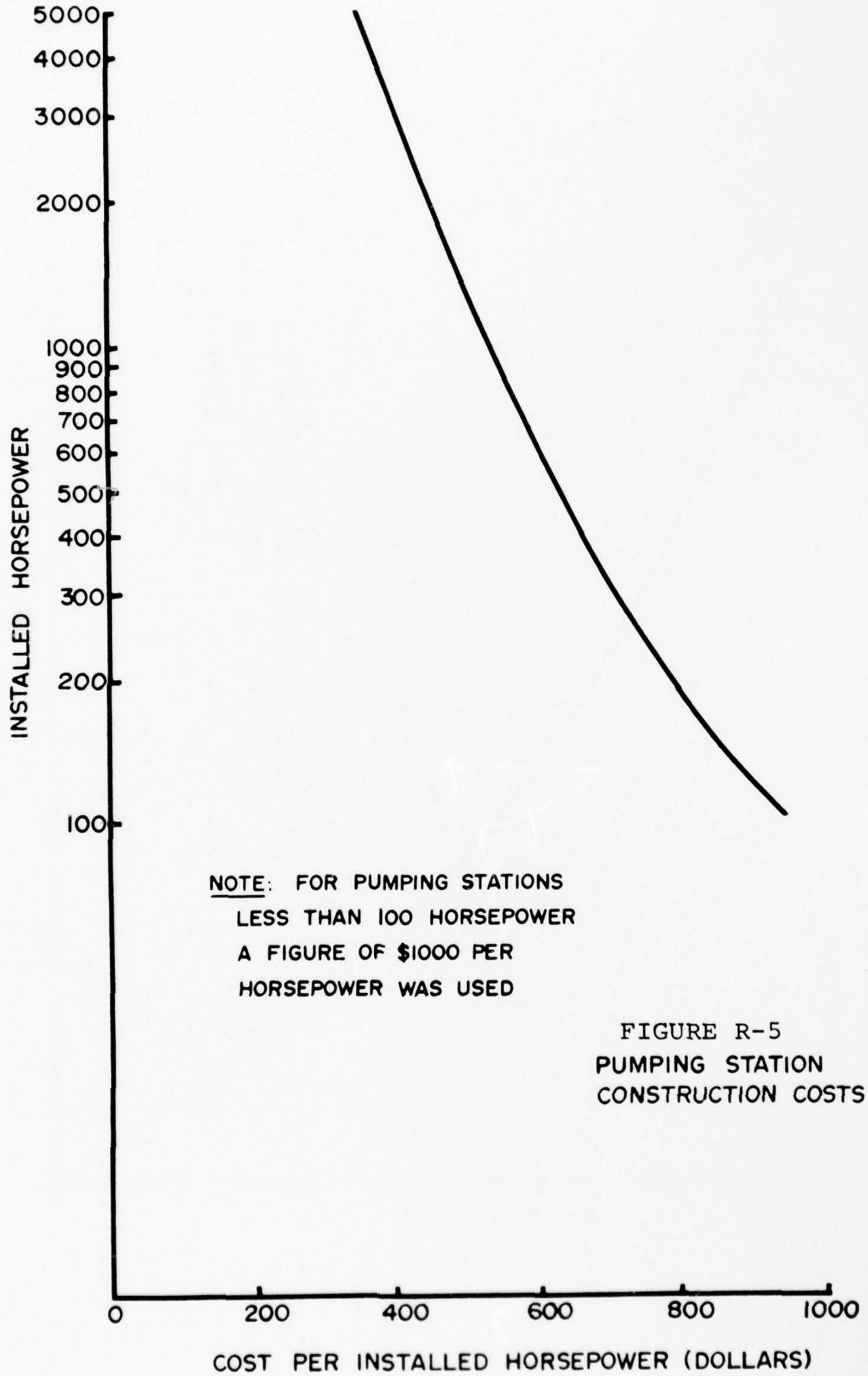


FIGURE R-4
WATER TREATMENT PLANT
COST VS CAPACITY



NOTE: FOR PUMPING STATIONS LESS THAN 100 HORSEPOWER A FIGURE OF $1000 PER HORSEPOWER WAS USED

FIGURE R-5
PUMPING STATION
CONSTRUCTION COSTS

SELF-SUPPLIED INDUSTRIAL WATER

The determination of industrial water use has traditionally presented a problem to the water supply planner because of the lack of specific published data. The major water-using industries are reluctant to disclose information on the amounts of water used in their processing, except in a manner that does not permit identification of the industry with its water use. This difficulty in the determination of existing industrial water use will, of course, affect any projections of future use.

Analysis of the present and future industrial water use in the NAR was accomplished in two separate steps. The first was accomplished by the Cornell University Department of Agricultural Economics under contract, and the second was completed by the NAR Study staff as part of the demand model. Both of these studies utilized generalized data on industrial water use presented in various publications of the Bureau of the Census, including data on employment, water intake and discharge, plant size, and number of plants. Present industrial water use data was reconciled with information from existing reports or studies and represents 1964 demands. Here, as in the case of determining future public water supply requirements, the demand model was not available at the beginning of the Study. Subsequent to the completion of the demand model, it was decided that a much more comprehensive analysis of industrial water requirements could be accomplished by use of the model. The estimated industrial water use requirements presented in this Appendix were developed from the model.

THE CORNELL METHOD

Employment in 1963 for 97 four-digit heavy water using industries (the level of classification in the Bureau of the Budget's (now Office of Management and Budget) Standard Industrial Classification Manual), was estimated by county from Census of Manufacturers data for 1963. These 97 industries were selected from 11 two-digit SIC categories: food; textiles; wood products; pulp and paper; chemicals; petroleum; rubber and plastics; leather; stone, clay and glass; primary metals, and machinery except electrical. Employment estimates for these industries were made using information on the number of plants per industry per county in each size group per industry. Employment for the remainder of the manufacturing sector outside of the 97 four digit industries estimated separately was taken as the residual of county employment according to the census data.

Employment projections for the bench mark years were then made for the 97 four-digit industries by county, using projections given by Office of Business Economics (OBE), Bureau of Commerce, for six two-digit water using industries where applicable, and average OBE rates of increase for all industry exclusive of petroleum and chemicals for other industries in the group of 97. Remaining employment after

subtracting estimates for the 97 industries from OBE employment projections of NAR Sub-regions by bench mark year is taken as the employment in the rest of manufacturing sector. Industrial employment was thus controlled by NAR Sub-region by the OBE employment projections.

To derive water intake and discharge estimates for the bench mark years, a primary estimate was made based on projected output together with water use coefficients modified for each bench mark year to reflect the (generally) increasing efficiency of water use observed from 1954 to 1964. To derive this estimate, employment projections estimated as described above were multiplied by OBE output indices; and 1964 intake and discharge rates modified by trends in the efficiency of water use were applied.

Two secondary estimates were made. The first was identical to the primary estimate, except that unmodified (generally higher) 1964 water intake and discharge rates were applied to output projections. This estimate, therefore, assumes no further changes in the efficiency of water use per unit of output. Another secondary estimate was made by applying unmodified 1964 water intake and discharge rates to employment projections only, not multiplied by output indices. This last secondary estimate assumes that output per employee can increase without requiring any increase in water use, implying a relatively great increase in the efficiency of water use per unit of output.

To estimate proportions of intake that will be brackish, census water use totals of brackish or saline water were allocated to industries in tidewater counties with a census record of brackish water use. Other intake was assumed to be freshwater. The estimates thus derived were projected to bench mark years.

The above method yields results for a given set of economic variables. Any change in basic assumptions which would alter the economic variables would require a complete reworking of the method to obtain new results. In addition the format used in this method cannot be integrated into the demand model. It was for these reasons that it was decided to develop a mathematical model method for determining industrial water use. The portion of the Cornell method dealing with the distribution of industrial water use in the NAR was retained and incorporated into the model.

MATHEMATICAL MODEL APPROACH

Industrial water use can be assumed to vary with the gross industrial output; i.e., the higher the output, the greater the water requirements and vice versa. It was felt that a logical method for determining future industrial water use would be to establish a relationship between the water use and the gross output. Gross output data for the North Atlantic Region was obtained from the Gross National

Product (GNP) projections in Appendix B.

The gross output distribution among the various industries was developed from the "Input/Output Structure of the United States Economy." an article which appeared in the November 1969 issue (Vol. 49, No. 11) of survey of Current Business, published by the U.S. Department of Commerce.

Regional water use coefficients, which allocate water use by industry in relation to the industry's output, were developed for 19 major water-using industries, utilizing information contained in various publications of the Bureau of the Census. These water use coefficients presented in gallons of water per dollar of industrial output were projected into the future. For those industries in which water use is mostly for the sanitary need of their employees, water use coefficients are based on the estimate of employees in the future. This implies a reduction in water use per dollar of output because the productivity per employee is projected to rise. For those industries in which water is a relatively small part of the manufacturing process, such as the machine and electrical industries, the water coefficients were considered constant. In the six heavy water using industries which are of importance in the N.A.R. region, projections of the water coefficients are based on industry estimates of future technology. For the Food, Textile, Petroleum Refining and the Primary Metals industries, water use improvements of 5 per cent were projected for the 1964 to 1980 period, 10 and 20 per cent respectively for the 1964 to 2000 and 1964 to 2020 period. For the Paper industry improvements of 10, 30 and 50 per cent and for the Chemical industry improvements of 15, 45 and 75 per cent were projected for the 1964 to 1980, 1964 to 2000 and 1964 to 2020 periods. The distribution of industrial water use in the North Atlantic Region developed as part of the Cornell Study was used to allocate industrial water use throughout 50 Sub-areas of the Region.

Additional coefficients were then developed which were used to divide the total water intake for each industry in each Sub-area into fresh, brackish and waste water, and also to determine fresh consumptive water use. Allocators were then developed which were used to split the fresh water intake into self-supplied and publicly-supplied. These coefficients and allocators were also developed from information in the Bureau of the Census publications.

The GNP figures in Appendix B were used to determine the present industrial use as well as the National Efficiency objective needs for the bench mark years of 1980, 2000 and 2020.

For the future, industrial water requirements under the Environmental Quality objective, the GNP resulting from the next lower population series was used. For the Regional Development objective, the GNP resulting from the next higher productivity level was used to determine the future industrial water needs. (Also see Alternative Objectives on pages R-7 and R-8).

The methodology as outlined above is very general. A more specific and detailed explanation of the procedures is contained in Appendix T annexes, which deal with the demand and supply models.

The industrial water supply requirements, both present and projected, presented in this Appendix represent total intake figures and do not take into consideration any reuse between plants. Net industrial demand figures (considering reuse) were used in the N.A.R. supply model to develop mixed objective devices and costs.

DEVICES AND COSTS

Devices

Water supply for industry is generally self-supplied and can be broken down into fresh, brackish and ground water. The breakdown of industrial water intake into surface and ground water was developed from information in Bureau of Census publications. The ratio of ground water to surface water that presently exists was held constant for the entire Study period. The quantities of brackish water that will be needed were developed by the mathematical model.

Intakes and pumping stations are the devices that are expected to be used for both the self-supplied fresh surface water and the brackish water, and wells will be used for ground water. Storage facilities for self-supplied industrial water needs were not considered in this appendix. There is no definitive way of determining individual plant size or location for which storage might be needed either for direct use or stream flow augmentation. The flow supply model considers storage requirements to meet all water withdrawal requirements including self-supplied industrial water. Treatment plants were not considered for industrial water supply. The desired quality of process water varies so greatly it was considered that water treatment, if needed, would be an internal feature of the particular industry and plant. The proposed devices were aggregated by the 21 Areas.

Costs

The basis for estimating pumping costs was the same as that developed for public water supply. Brackish water pumping costs do not differ from fresh water pumping costs. Ground water costs were determined in a similar fashion to that developed for public water supply.

CHAPTER 3. REGIONAL SUMMARY

The North Atlantic Region includes all the river basins draining into the Atlantic Ocean north of the Virginia-North Carolina border, Chesapeake Bay, Lake Champlain drainage within the United States, and St. Lawrence River drainage south of the junction of the St. Lawrence River and the International boundary. All or portions of thirteen states and the District of Columbia are included in the Region, which encompasses a land area of about 167,000 square miles.

The Region contains only 5% of the Nation's land area but 25% of its population, 29% of the personal income and 30% of the manufacturing employment. Of the more than 47,000,000 million people in the Region, some 26,000,000 million live in the five major metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington, D.C. Recreation and forestry are the main economic factors in the northern portion of the Region, and agricultural generally dominates the southern portion except for some centers of light industry. In the middle part of the Region are concentrated the centers of industry, commerce, finance and transportation.

The NAR is generously supplied with water resources. The annual precipitation averages from 40 to 45 inches and on a total volume basis, is adequate to satisfy water supply demands. Ground waters are extensive and in many Areas are relatively undeveloped. The recent drought in the Northeast (1961-1966) was the longest and most severe in history of the Region, with precipitation in portions of the Region averaging one inch a month less than normal for a period of about four years. The drought emergency demonstrated the inadequacy of existing facilities to properly utilize the available water resources of the Region with respect to the development of dependable sources, and the adequacy of conveyance facilities, distribution systems and treatment plants.

For purposes of the Study, the Region was divided into 21 Areas, which for the most part, are established along hydrologic lines. The water supply requirements for each of these Areas are presented in the Area Summaries. In order to more easily pinpoint the water supply needs of the Region, many of the 21 areas were further divided into sub-areas. In each of the Area summaries, the public water supply and industrial water supply are examined with respect to present conditions and projected requirements. Existing conditions in 1965 were designated as present use, or base year, and are the basis for developing the needs for the bench mark planning years of 1980 and 2000 and the Study target date of 2020. Future requirements were projected for the three NAR Study objectives, Environmental Quality, National Efficiency and Regional Development. Devices proposed to satisfy projected needs, and the estimated costs of these devices, are also included in the Area Summaries. The forecasting procedure for the needs, devices and costs are covered in Chapter 2, Methodology.

Public water supply was considered to be that water supplied from a central system, without regard to the size or purpose. Industrial water supply was considered to be the water intake requirements of 19 major water-using industries.

Rural domestic water needs are based on rural population, which is defined for the purposes of this investigation as all those people who are not connected to central water supply systems. Livestock water requirements are based on projections of livestock populations and milk and egg sales. Rural water needs are summarized in Chapter 5.

PUBLIC WATER

PRESENT USE

Water from public or central water supply systems satisfies many needs -- domestic, industrial, commercial and municipal. As discussed in Chapter 2, the parameters used to determine future public water supply requirements are population served and per capita income. Table R-1 shows the present public water supply use, population, population served and per capita income for the Region's 21 areas.

TABLE R-1
PRESENT PUBLIC WATER SUPPLY BY AREA

AREA	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
1	109	38	1,721	6
2	147	107	2,181	11
3	154	117	2,216	17
4	163	149	2,327	14
5	162	100	2,036	13
6	488	399	2,530	50
7	914	858	2,857	106
8	1,679	1,445	2,866	191
9	4,939	4,798	2,913	617
10	2,062	1,719	3,149	255
11	533	357	2,217	51
12	2,136	1,557	2,811	226
13	11,083	10,708	3,521	1,404
14	4,387	4,124	3,483	513
15	6,719	5,998	2,940	800
16	760	710	3,018	86
17	3,362	2,627	2,397	340
18	2,330	1,791	2,817	260
19	3,236	2,536	3,041	360
20	316	146	2,298	18
21	1,698	1,343	2,431	185

The total population of the Region is 47,514,200, of which 41,770,000 people, or approximately 88%, are supplied with water from some 1,200 central water supply systems. Present use averages about 5.5 billion gallons per day, (b.g.d.), of which 4.7 b.g.d. is for domestic use, with the remainder used for industrial, commercial and municipal purposes.

Surface waters supply approximately 76% of the water used by the public water supply systems, with the remainder developed from ground water sources.

FUTURE USE

The Region's personal income and population are projected to increase throughout the study period. General assumptions applicable to the projections of growth and a variety of specific assumptions related to population, labor force, total employment, private employment, hours worked and production per man-hour are discussed in Appendix B, Economic Base. As indicated previously in Chapter 2, projections were developed for the Environmental Quality and Regional Development objectives by assuming variations of the middle value National Efficiency estimates. In connection with population growth, it is noted that the NE and RD annual growth rate of 1.3% and the EQ rate of 1.0% are both substantially below the historic regional growth rate of 1.6% for 1950 through 1965. Firther material on variants in projections is contained in Appendix T, Plan Formulation.

The anticipated growth of population and income indicate that the public water supply requirements can be expected to increase. The population served is also expected to increase from the present 88% to 92% by the year 2020. Table R-2 summarized the present and projected water supply needs, populations, populations served and the per capita incomes for the entire North Atlantic Region.

The projections used are based on an extrapolation of observed trends including the downtrend in the annual population growth rate. If new data shows that these trends change or greatly accelerate, projections and the estimates based on these projections must be changed. However, even large changes in the growth assumptions will not greatly change the water supply estimates for 1980.

With respect to the National Efficiency objective; the anticipated public water requirements are expected to be 7,187 m.g.d. in 1980, 10,592 m.g.d. in 2000, and 15,664 m.g.d. in 2020, almost three times the present use. Population served has been projected to increase to 49.3 million in 1980, 62.7 million in 2000, and 79.8 million in 2020, from the present value of 41.8 million. Per capita income is expected to increase to $4,551 in 1980, $7,779 in 2000, and $13,315 in 2020, about four times the present level.

TABLE R-2
PUBLIC WATER SUPPLY
NORTH ATLANTIC REGION

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	47,377	41,633	3,232	5,523
1980				
EQ	53,805	47,549	4,338	6,882
NE	55,641	49,199	4,551	7,187
RD	55,641	49,199	4,682	7,242
2000				
EQ	63,903	57,521	7,002	9,566
NE	69,613	62,562	7,779	10,592
RD	69,613	62,562	8,072	10,925
2020				
EQ	73,426	67,852	11,426	13,106
NE	86,210	79,645	13,315	15,664
RD	86,210	79,645	14,000	16,058

TABLE R-3
PUBLIC WATER SUPPLY DEVICES AND COSTS - NAR
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	607,000	246.0	720,000	292.0	750,000	302.0
Treatment Plant	418	310.0	512	368.0	527	382.0
Intake & Pumping	334	1.8	409	2.2	423	2.3
Diversion	63	26.5	78	32.8	81	34.2
Ground Water	310	12.3	379	15.6	426	15.5
2000						
Storage	1,313,000	377.8	1,707,000	561.2	1,746,000	574.3
Treatment Plant	1,605	856.0	2,171	1,033.9	2,227	1,080.8
Intake & Pumping	1,023	5.5	1,290	7.0	1,326	7.2
Diversion	436	209.6	692	245.6	698	246.6
Ground Water	649	28.0	826	35.7	852	36.7
2020						
Storage	400,000	175.9	936,000	310.4	1,031,000	475.9
Treatment Plant	2,508	1,018.8	3,526	1,402.8	3,914	1,445.1
Intake & Pumping	1,586	8.6	2,410	13.0	2,620	14.1
Diversion	1,088	233.3	1,673	382.0	1,827	427.0
Ground Water	584	23.8	798	34.9	873	36.0

Note: Storage quantities in acre-feet; other devices in m.g.d.

FUTURE DEVICES AND COSTS

In order to satisfy the future public water supply needs of the Region, additional facilities will be required at different time frames during the Study period. These facilities include additional reservoir storage, intakes and pumping stations, major interbasin ground water development and water treatment plant capacity.

Table R-3 shows the devices proposed to satisfy the future needs, their estimated costs and the years in which the devices would be required.

The devices and costs developed for public water supply were for a single purpose only and do not necessarily correspond to the devices and costs resulting from the supply model for the NAR, inasmuch as the supply model concerns itself with the mixed objective for the Region with respect to all water withdrawals. Device and cost information will be extracted from this Appendix to be used in the development of the overall recommended plan for the Region. Cost figures have been adjusted to 1970 price levels.

SELF-SUPPLIED INDUSTRIAL WATER

PRESENT USE

In this Appendix, self-supplied industrial water is considered to be that portion of the total industrial water intake developed by industries from their own sources which could be fresh, brackish or waste water. The total industrial water intake for the Region is 7,340 m.g.d., of which 3,836 m.g.d. are self-supplied fresh water, 2,756 m.g.d. are brackish water, 120 m.g.d. are waste water and 628 m.g.d. are publicly-supplied fresh water. Approximately 17% of the self-supplied fresh water is developed from ground water. There are 19 water-using industries in the Region which were considered in assessing the industrial water supply. Table R-4 shows these industries and lists their total use, self-supplied fresh, publicly-supplied fresh, waste water, brackish water and fresh consumptive use. Mining and Power Plant cooling are considered separate in Appendices H Minerals and P Power, respectively.

FUTURE USE

The projected economic growth of the Region is reflected in the anticipated increases in industrial water requirements. By 2020, the total industrial intake is expected to be 35,663 m.g.d. (EQ), 40,182 m.g.d. (NE) and 44,561 m.g.d. (RD), of which 17,451 m.g.d., 19,592 m.g.d. and 21,679 m.g.d., respectively, will be self-supplied fresh water. The largest self-supplied fresh water-using industries in 2020 are shown in Table R-5.

TABLE R-4
PRESENT INDUSTRIAL WATER WITHDRAWALS
NORTH ATLANTIC REGION
(m.g.d.)

INDUSTRY	TOTAL USE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Chemicals & Plastics	2,362	1,039	159	0	1,165	193
Primary Metals	1,675	770	63	120	722	207
Paper	1,166	1,027	41	0	97	91
Petroleum	740	206	12	0	523	25
Food	392	157	85	0	150	38
Transportation Equipment	266	196	70	0	0	15
Machine Equipment	142	97	42	0	3	8
Glass & Clay	130	81	10	0	39	34
Fabrics	120	84	25	0	12	13
Electrical Equipment	97	53	43	0	0	8
Rubber	91	40	13	0	39	7
Metal Products	72	41	31	0	0	5
Scientific Instruments	40	22	18	0	0	3
Leather	16	7	2	0	6	3
Miscellaneous Manufacturing	13	7	6	0	0	1
Apparel	6	3	3	0	0	1
Tobacco	5	3	2	0	0	0
Printing	4	2	2	0	0	0
Furniture	2	1	1	0	0	0
Wood Products	1	1	0	0	0	0
TOTAL NAR	7,340	3,837	628	120	2,756	652

Note: Total Use column may not agree as data was rounded by computer.

TABLE R-5
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - NAR
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Primary Metals	4,737	5,336	5,917
Paper	4,093	4,611	5,113
Chemicals & Plastics	2,316	2,609	2,893
Petroleum	1,541	1,735	1,924
Food	1,023	1,152	1,278
Transportation Equipment	867	976	1,083
Machine Equipment	782	881	977
Glass & Clay	731	823	913
Fabrics	564	635	704
Electrical Equipment	450	507	562

Brackish water intake will be mainly for the primary manufacturing, petroleum, chemicals and plastics, food and paper industries. Its use is predicted on an estimate of technological change that will permit its use instead of fresh water. Similarly waste water use as a substitute for fresh water is expected to be possible through the application of a developing technology.

Present and projected industrial water requirements for the Region are shown in Table R-6.

TABLE R-6
INDUSTRIAL WATER SUPPLY - NORTH ATLANTIC REGION
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	7,308	3,819	607	120	2,762	628
1980						
EQ	13,266	6,808	1,025	254	5,179	1,149
NE	13,269	6,809	1,028	254	5,178	1,150
RD	13,620	6,991	1,050	260	5,316	1,177
2000						
EQ	22,962	11,491	2,055	555	8,861	1,987
NE	24,237	12,107	2,198	585	9,347	2,105
RD	25,836	12,884	2,373	624	9,965	2,253
2020						
EQ	35,635	17,451	3,630	1,138	13,444	3,115
NE	40,182	19,592	4,157	1,282	15,151	3,567
RD	44,561	21,679	4,650	1,422	16,816	3,948

FUTURE DEVICES AND COSTS

Self-supplied industrial water needs in the Region are presently satisfied by river and/or lake intakes, ground water, brackish sources and waste water. For the most part, it is anticipated that the future needs will be met in a similar fashion and in approximately the same proportion. In some of the Areas, particularly in the later stages of the Study period, the availability of surface water is expected to be limited so as to preclude development for private use. This may necessitate a shift of all or a part of the fresh water needs from self-supplied to publicly-supplied, or may require regulation which will

either limit withdrawals or require a cost sharing by industry of facilities needed to maintain minimum flows in the Region's rivers. In addition, there are some Areas where the projected ground water requirements are expected to exceed the limit of practical development which necessitates a shift to surface supplies to meet the fresh water industrial needs. These conditions are discussed in the Area Summaries.

Table R-7 indicates devices proposed to satisfy the incremental increases in self-supplied industrial water and the estimated costs of these facilities.

TABLE R-7
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - NORTH ATLANTIC REGION
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	2,487	13.5	2,488	13.5	2,643	14.3
Brackish Water						
Intake & Pumping	2,417	13.1	2,416	13.1	2,554	13.8
Ground Water	502	13.5	502	13.5	532	14.3
Waste Water	134	.7	134	.7	140	.8
2000						
Fresh Water						
Intake & Pumping	3,886	21.0	4,433	23.9	4,943	26.7
Brackish Water						
Intake & Pumping	3,682	19.9	4,169	22.5	4,649	25.1
Ground Water	797	44.4	866	48.6	950	53.2
Waste Water	301	1.6	331	1.8	364	2.0
2020						
Fresh Water						
Intake & Pumping	4,943	26.7	6,497	35.1	7,782	42.0
Brackish Water						
Intake & Pumping	4,583	24.7	5,804	31.3	6,851	37.0
Ground Water	1,019	57.9	993	53.9	1,013	53.1
Waste Water	583	3.1	697	3.8	798	4.3

The devices and costs developed for industrial water supply were for a single purpose only, and do not necessarily correspond to those resulting from the NAR Supply Model. Device and cost information will be extracted from this Appendix for use in the development of the overall recommended plan for the Region. Cost figures have been adjusted to 1970 price levels.

DISCUSSION

While the data for present and future water supply contained in this Appendix is only a part of the water management picture, certain preliminary conclusions can be drawn and comparisons made to highlight future water supply and water supply planning problems.

Table R-7A, Water Supply Summary, presents a preliminary comparison between gross needs and resources. For each area three resource values are shown: Average Annual Runoff, Existing Resource and Total Practical Development. Existing Resource is the 7-day average that will be available after several reservoirs are completed which are now under construction or in the final planning stage. Total Practical development is that amount that can be made available in each basin with full use of those storage sites and groundwater resources that reasonably can be expected to be developed. The needs summarized for the 1980 and 2020 time horizon are gross totals for public water supplies and for independent supplies of 19 major water using industries. Data in TableR-64show that in Area 13 the gross water requirements in 2020 exceed the runoff; in Area 14 the 2020 needs are about equal to the annual runoff; in Areas 9, 15 and 18, 2020 needs exceed the limits of practical development; and in Areas 8, 10, 17, 19, 20 and 21, gross needs for 2020 exceed the existing resources.

Three approaches can be used to allow resources to fulfill needs in any of the areas named in the previous paragraph. The net water demands can be made less than the gross demand through reuse or limitations on use, development can take place or a combination of these two actions can occur. A considerable amount of reuse comes naturally from the physical locations of industries and towns. Upstream users discharge their water and it is reused downstream. Other reuses will have to be encouraged. The NAR water withdrawal models which are discussed in Appendix T, Plan Formulation, takes into consideration the fact that more than one user can withdraw the same water if they are located at different points on a stream. The model also assumes improved technology leading to reduced industrial water demand.

Framework planning, the purpose of the NAR Study is not sufficiently detailed to develop projects. Detailed basin or project planning is needed. Detailed water supply plans have been prepared or are in progress in the NAR as part of the North Eastern United States Water Supply (NEWS) Study, The Delaware River Basin Comprehensive Plan, the Susquehanna River Basin Study and other planning studies. Different exist between water supply data developed in those studies and in the NAR Study. This should be expected since the NAR methodology represents

a regional overview and the other studies represent detailed, specific location oriented studies incorporating engineering, economic, institutional, social and environmental viewpoints specifically applicable at each location. Some of the major differences or similarities between the water supply data of these studies are discussed here.

Preliminary findings in the NEWS study agree with the NAR results for Area 13 with only small differences in 1980 and 2020 (less than 10 per cent) due to differential growth rates assumed for each time period. In Area 14, a detailed NEWS study showed smaller needs than the NAR results because of the NAR assumption that industrial use be curbed due to lack of resources, costs and crowding. State estimates for Area 14, however, are closer to NAR results. In Area 19, needs for water supply are very similar. Preliminary findings of the NEWS Study, however, call for significantly more storage by 1980 due to the unusually low storage within the Washington Metropolitan area water supply systems and the need to maintain low flows for in stream water needs.

Differences in water needs found in the Susquehanna Study and in the NAR Study are based largely on different assumptions in population and economic growth. The Susquehanna Economic Base Study, completed before the NAR, assumes a significantly greater population growth, a larger percentage of people living in rural areas or small towns and a larger growth in services and low water using industries. The NAR study is based on lower total population growth figures, greater concentration in towns with public water supplies and a greater increase in heavy water using industries. The results of these two sets of assumptions is that public water supply needs are nearly the same in both studies in 1980 and 2000 and somewhat higher in the Susquehanna study in 2020. Rural water supply needs are much higher in the Susquehanna study and Industrial self-supplied water needs show higher figures in the NAR. The differences are not very large in 1980 but become large in 2020. To judge which assumptions are better is not possible but as the results are nearly alike for 1980, the time period for which decisions must be made now, either is reasonable.

TABLE R-7A

WATER SUPPLY SUMMARY
(Figures in m.g.d.)

	Average Annual Runoff	Existing Resource 1/	Total Practical 2/	Gross Water Supply Requirements 3/ 1980 EQ	1980 NE	1980 RD	2020 EQ	2020 NE	2020 RD	2020 NE Requirements Exceed Existing Resource	2020 NE Requirements Exceed Total Practical
Area 1	12,115	828	3,980	42	43	45	130	149	163		
Area 2	9,650	2,568	5,814	224	224	231	656	743	823		
Area 3	6,500	1,657	2,816	98	99	101	203	230	253		
Area 4	3,985	1,124	2,442	152	153	156	297	338	374		
Area 5	7,520	1,029	2,582	121	121	125	294	333	366		
SUB-REGION A	39,770	7,206	17,634	637	640	658	1,580	1,793	1,979		
Area 6	4,615	596	1,889	134	136	140	309	358	381		
Area 7	5,380	670	2,894	229	236	235	487	566	603		
Area 8	12,230	1,697	5,159	693	703	717	1,677	1,918	2,086	x	
Area 9	5,280	800	1,832	1,031	1,065	1,080	1,971	2,312	2,440	x	x
Area 10	4,870	394	1,373	492	506	513	1,032	1,206	1,260	x	
SUB-REGION B	32,375	4,157	13,147	2,579	2,645	2,685	5,476	6,350	6,770		
Area 11	12,145	1,640	3,473	212	215	219	410	477	514		
Area 12	13,190	2,261	7,838	771	786	800	1,899	2,186	2,343		
Area 13	1,900	623	1,212	1,675	1,743	1,757	2,542	3,035	3,071	x	x
SUB-REGION C	27,235	4,524	12,523	2,658	2,744	2,776	4,851	5,694	5,928		
Area 14	2,580	852	1,496	1,082	1,112	1,125	2,119	2,458	2,583	x	x
Area 15	13,200	4,840	7,562	2,860	2,905	2,965	7,733	8,827	9,582	x	x
Area 16	2,450	845	1,065	134	140	141	310	371	374		
SUB-REGION D	18,230	6,537	10,123	4,076	4,157	4,231	19,162	11,656	12,539		
Area 17	24,890	1,741	8,756	1,018	1,035	1,052	2,620	2,991	3,254	x	
Area 18	5,500	1,085	1,468	631	644	654	1,462	1,680	1,801	x	x
SUB-REGION E	30,390	2,826	10,224	1,649	1,679	1,706	4,082	4,671	5,055		
Area 19	8,970	776	3,552	1,017	1,038	1,057	2,402	2,784	2,981	x	
Area 20	3,680	78	1,702	108	108	112	170	197	212	x	
Area 21	7,450	674	2,938	966	985	1,007	1,834	2,096	2,273	x	
SUB-REGION F	20,100	1,528	8,192	2,091	2,131	2,176	4,406	5,077	5,466		
TOTAL NAR	168,100 4/	26,778 4/	71,843 4/	13,690	13,997	14,232	30,557	35,256	37,737		

1/ Available before use; includes allowance for consumption, yield of existing storage, and yield of the following authorized projects: Beltzville and Tocks Island in Area 15, Raystown in Area 17, and Gathright in Area 21. Flow developed for export is included in resource of the originating Area.
2/ Sum of surface and ground water available after full development of reasonably available sites.
3/ Gross sum of publicly and self-supplied water for municipal and industrial uses except mining and the cooling of electric power plants.
4/ Includes flow from contributing drainage area in Canada (4,096 square miles in Area 1, 625 square miles in Area 5, and 114 square miles in Area 8).

CHAPTER 4. AREA SUMMARIES

AREA 1. ST. JOHN RIVER BASIN

PUBLIC WATER

Present Use

Area 1 is the least populated of the 21 Areas in the North Atlantic Region. Twelve central water supply systems deliver an average of 6 m.g.d. to about 38,000 people, or roughly 35% of the Area's total population of 109,000. Surface supplies, consisting of river intakes and small impoundments, provide approximately 84% of the water supply for these systems, with the balance supplied from ground water.

Future Use

The population for the NE objective is projected to be 161,000 by the year 2020, an increase of 50%. In the same time frame, the population served is expected to slightly more than double to a figure of 81,000, or roughly 50% of the total population. Per capita income is anticipated to increase by almost 500%. As a result of these increases in population served and per capita income, the public water supply requirement for the National Efficiency objective is expected to be 17 m.g.d. by the year 2020, almost a three-fold increase.

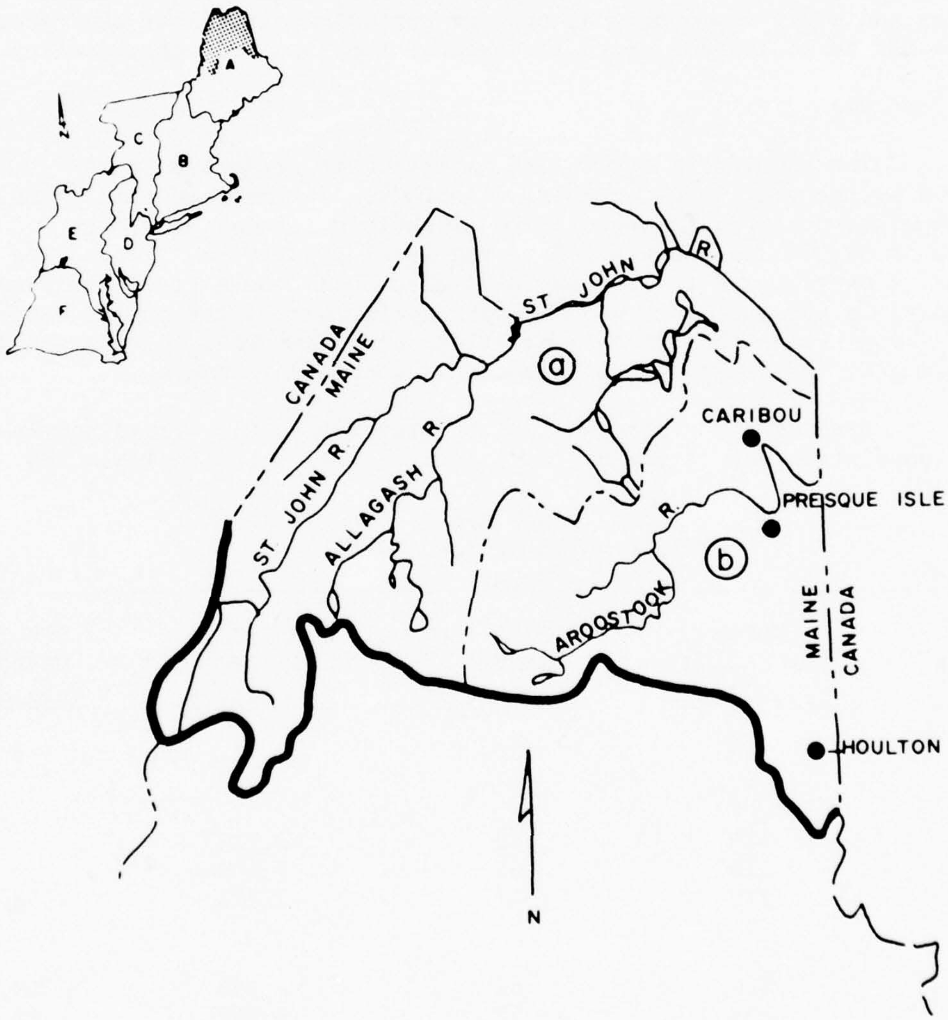
Present and projected public water supply use, total population, population served and per capita income are shown in Table R-8.

TABLE R-8
PUBLIC WATER SUPPLY - AREA 1

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	109	38	1,721	6
1980				
EQ	114	45	2,514	7
NE	118	47	2,640	8
RD	118	47	2,713	8
2000				
EQ	126	57	4,198	10
NE	138	62	4,669	11
RD	138	62	4,795	11
2020				
EQ	138	69	7,237	14
NE	161	81	8,438	17
RD	161	81	8,666	17

FIGURE R-6

AREA I ST. JOHN RIVER BASIN



Future Devices and Costs

The major portion of the future public water supply needs in Area 1 can be met with existing facilities. However, for all bench mark years, some additional river or lake intake and pumping facilities and ground water development will be needed. The existing water treatment plant capacity is expected to be sufficient through 1980, after which additional capacity will be required. There is no anticipated need for storage impoundments.

Table R-9 indicates devices that could meet the incremental increases in public water supply and the estimated costs to furnish these facilities.

TABLE R-9
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 1
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	0.5	0.600	1.0	1.200	1.0	1.200
Intake & Pumping	0.5	.003	1.0	.005	1.0	.005
Diversion	-	-	-	-	-	-
Ground Water	0.2	.010	0.3	.020	0.3	.020
2000						
Storage	-	-	-	-	-	-
Treatment Plant	3.0	3.700	3.0	3.700	3.0	3.700
Intake & Pumping	2.0	.011	2.0	.011	2.0	.011
Diversion	-	-	-	-	-	-
Ground Water	0.5	.020	0.5	.020	0.5	.020
2020						
Storage	-	-	-	-	-	-
Treatment Plant	3.8	4.400	5.6	5,900	5.6	5.900
Intake & Pumping	2.4	.013	3.5	.019	3.5	.019
Diversion	-	-	-	-	-	-
Ground Water	0.7	.020	1.0	.030	1.0	.030

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 1 is 18 m.g.d., all but 1 m.g.d. of which is self-supplied fresh water. The two main water-using industries in the Area are paper and food with total fresh water intakes of 11 m.g.d. and 7 m.g.d., respectively. No brackish or waste water is used for industrial purposes. The water supply is obtained mainly from surface sources.

Future Use

Paper and food will continue to be the largest industrial water-users in the Area, with the paper industry intake ranging from 24 m.g.d. for the 1980 EQ objective to 85 m.g.d. under the 2020 RD objective, and the food industry intake ranging from 13 m.g.d. to 60 m.g.d. for the same years and objectives. Other minor water-using industries that can be expected to develop in the Area include machine equipment, glass and clay, metal products, electrical equipment and transportation equipment.

Present industrial water-use and projected industrial water requirements for Area 1 are shown in Table R-10.

TABLE R-10
INDUSTRIAL WATER SUPPLY - AREA 1
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	18	17	1	0	0	1
1980						
EQ	37	35	2	0	0	2
NE	37	35	2	0	0	2
RD	37	37	0	0	0	3
2000						
EQ	72	69	3	0	0	4
NE	75	72	3	0	0	5
RD	80	77	3	0	0	5
2020						
EQ	121	116	5	0	0	7
NE	137	132	5	0	0	8
RD	151	146	5	0	0	8

Future Devices and Costs

The industrial water supply needs are currently met by river and/or lake intakes and by wells. It is anticipated that the future needs for self-supplied industrial water will continue to be satisfied in the same manner and in approximately the same proportion.

The devices that could furnish the incremental increases in industrial water supply and their estimated costs are shown in Table R-11.

TABLE R-11
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 1
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Intake & Pumping	17	.09	17	.09	19	.10
Ground Water	1	.03	1	.03	1	.03
2000						
Intake & Pumping	32	.17	35	.19	38	.21
Ground Water	2	.09	2	.09	2	.09
2020						
Intake & Pumping	44	.24	56	.30	65	.35
Ground Water	3	.13	4	.16	4	.16

AREA 2. PENOBSCOT RIVER BASIN

PUBLIC WATER

Present Use

The present population of Area 2 is 147,000, of which 73%, or 107,000 people, receive their water supply from 22 central water systems. These public systems which distribute an average of 11 m.g.d. of water obtain approximately 80% of their supply from surface sources consisting of river intakes and small impoundments. The remainder is developed from ground water supplies.

Future Use

The total population for the NE objective has been projected to increase by 50% to 219,000 by the year 2020. For the same time frame, the population served is expected to increase by 80% to 196,000, and the per capita income is anticipated to be almost five times as large as the present value of $2,181. The NE public water supply requirements are expected to increase to 40 m.g.d. as a result of the growth of the population served and per capita income.

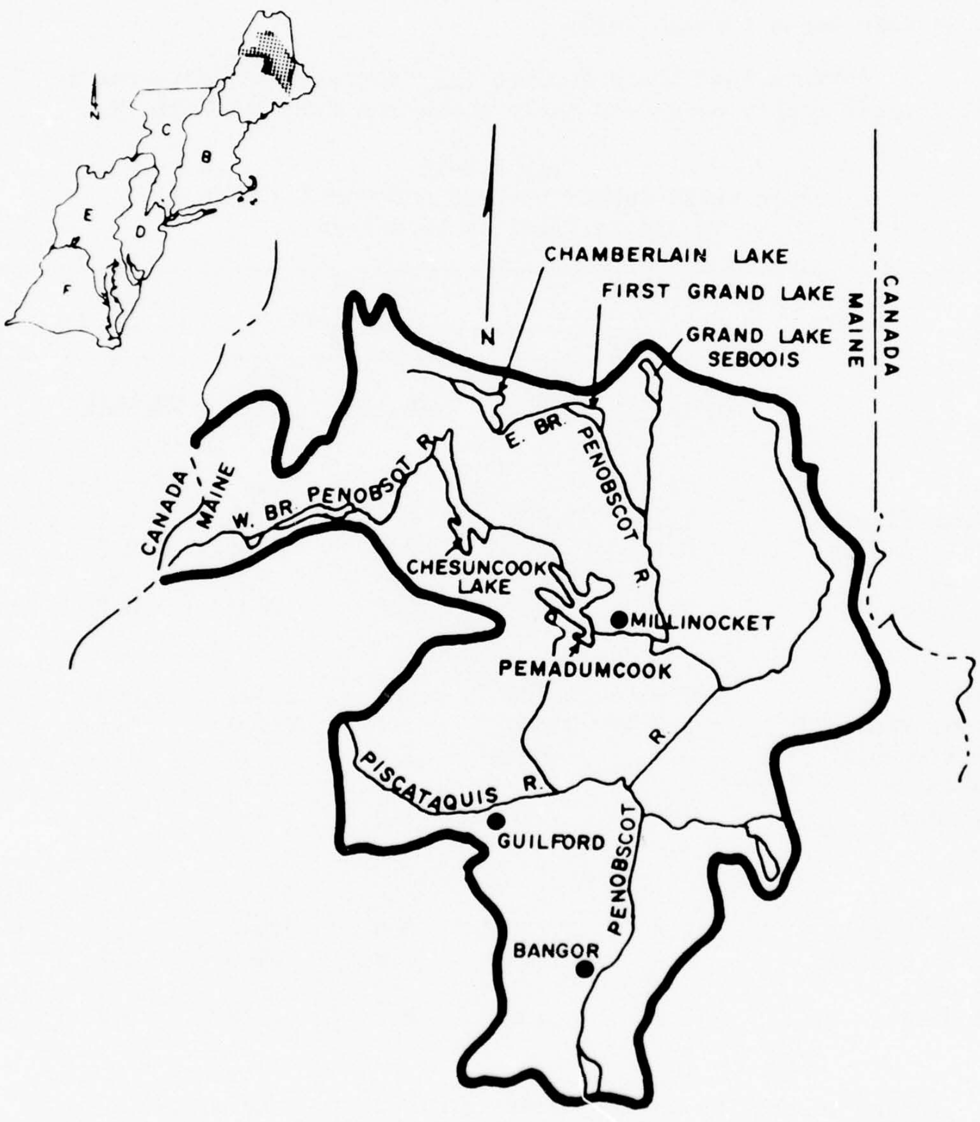
Present public water supply conditions and projected public water supply requirements, total population, population served and per capita income are shown in Table R-12.

TABLE R-12
PUBLIC WATER SUPPLY - AREA 2

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	147	107	2,181	11
1980				
EQ	153	117	3,195	15
NE	159	120	3,357	15
RD	159	120	3,448	15
2000				
EQ	171	140	5,318	23
NE	186	152	5,910	24
RD	186	152	6,073	25
2020				
EQ	186	168	9,149	35
NE	219	196	10,663	40
RD	219	196	10,956	43

FIGURE R-7

AREA 2 PENOBSCOT RIVER BASIN



Future Devices and Costs

Existing facilities can supply the major portion of the Area's future public water supply needs. However, some additional intake and pumping stations, water treatment plants and ground water development will be required for all bench mark years. By the year 2000, additional reservoir capacity will be needed to supplement existing storage. This additional capacity will be sufficient to satisfy the storage needs through 2020.

Devices that could furnish the incremental increases in public water supply needs and their costs are shown in Table R-13.

TABLE R-13
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 2
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	1.1	1.800	1.1	1.800	1.1	1.800
Intake & Pumping	0.7	.004	0.7	.004	0.7	.004
Diversion	-	-	-	-	-	-
Ground Water	0.7	.030	0.7	.030	0.7	.030
2000						
Storage	7,900	3.400	8,900	3.800	9,900	4.200
Treatment Plant	2.0	2.000	2.1	2.100	2.3	2.700
Intake & Pumping	1.0	.005	1.1	.006	1.2	.006
Diversion	-	-	-	-	-	-
Ground Water	1.5	.070	1.6	.070	1.8	.080
2020						
Storage	-	-	-	-	-	-
Treatment Plant	2.8	2.800	3.6	3.500	4.2	4.000
Intake & Pumping	1.4	.008	1.8	.010	2.1	.011
Diversion	-	-	-	-	-	-
Ground Water	2.2	.100	2.9	.120	3.2	.130

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use.

The total industrial water intake in the Area is 101 m.g.d., of which 98 m.g.d. are self-supplied fresh water. The paper industry is the only major water-user in the Area with a total intake of 98 m.g.d. There is no brackish or waste water industrial use. The self-supplied industrial water is mostly from surface supplies.

Future Use.

The paper industry is projected to be the dominant industrial water-user in the Area, with a total intake range from 206 m.g.d. for the 1980 EQ objective to 743 m.g.d. for the 2020 RD objective. Other industries that can be expected to develop with relatively low intake requirements include fabric, food, leather, glass and clay, electrical equipment, transportation equipment, metal products, wood products and scientific instruments.

Area 2's present and projected industrial water requirements are shown in Table R-14.

TABLE R-14
INDUSTRIAL WATER SUPPLY - AREA 2
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	101	98	3	0	0	5
1980						
EQ	217	209	8	0	0	10
NE	218	209	9	0	0	10
RD	223	216	7	0	0	10
2000						
EQ	406	393	13	0	0	19
NE	428	414	14	0	0	20
RD	457	440	17	0	0	21
2020						
EQ	621	621	28	0	0	31
NE	728	703	25	0	0	36
RD	806	780	26	0	0	41

Future Devices and Costs

The industrial water supply needs are currently met by river and/or lake intakes and by wells. It is expected that the future needs will continue to be satisfied in the same manner and in approximately the same proportion that now exists.

Table R-15 indicates the devices that could supply the incremental increases in industrial water supply and their estimated costs.

TABLE R-15
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 2
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Intake & Pumping	108	.58	108	.58	114	.62
Ground Water	3	.13	3	.13	4	.16
2000						
Intake & Pumping	178	.96	199	1.07	217	1.17
Ground Water	6	.26	6	.26	7	.30
2020						
Intake & Pumping	221	1.19	280	1.51	330	1.78
Ground Water	7	.30	9	.39	10	.43

AREA 3. KENNEBEC RIVER BASIN

PUBLIC WATER

Present Use

The total population of Area 3 is 154,000, of which 117,000 people, or 76%, are supplied with water from 32 central water supply systems. These systems distribute an average of 17 m.g.d., of which approximately 82% is derived from surface sources consisting of river intakes and small impoundments. Ground water developments furnish the remainder.

Future Use

Under the NE objective, the total population of the Area has been projected to grow to 217,000 by 2020, a 40% increase over the present. In conjunction with the growth in total population, the population served is expected to increase to 183,000, an increase of almost 60%. Per capita income is anticipated increase from $2,216 to $11,454. As a result of these increases, the projected public water supply requirement for the year 2020 is 41 m.g.d., about 2.5 times the present 17 m.g.d.

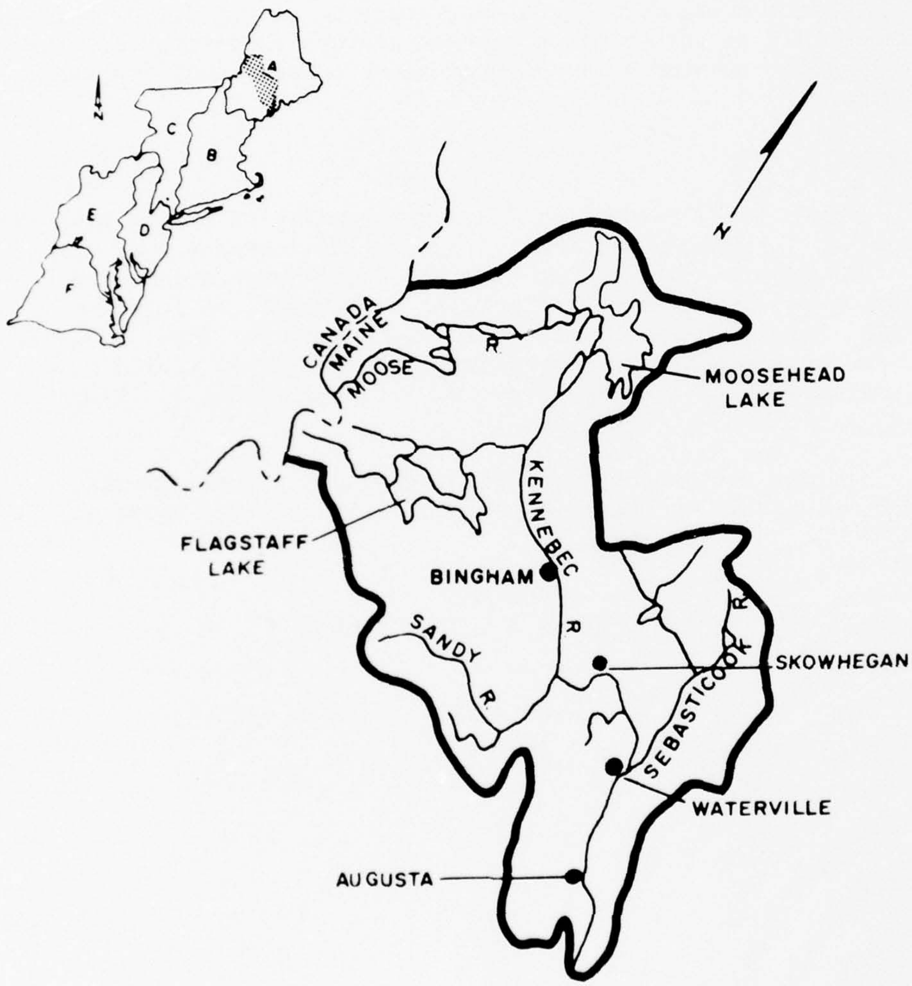
Present and projected public water supply requirements, population, population served and per capita incomes are shown in Table R-16.

TABLE R-16
PUBLIC WATER SUPPLY - AREA 3

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	154	117	2,216	17
1980				
EQ	162	128	3,226	20
NE	167	133	3,392	21
RD	167	133	3,484	21
2000				
EQ	173	140	5,487	27
NE	188	153	6,102	29
RD	188	153	6,267	30
2020				
EQ	185	155	9,823	35
NE	217	183	11,454	41
RD	217	183	11,763	41

FIGURE R-8

AREA 3 KENNEBEC RIVER BASIN



Future Devices and Costs

Future public water supply needs in Area 3 can be met through additional intake and pumping facilities, wells and treatment plant capacity. There is no anticipated need for additional reservoir storage.

Table R-17 shows devices for meeting the incremental increases in public water supply needs and their estimated costs.

TABLE R-17
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 3
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	1.7	1.200	2.3	3.000	2.3	3.000
Intake & Pumping	1.7	.009	2.3	.012	2.3	.012
Diversion	-	-	-	-	-	-
Ground Water	0.5	.017	0.7	.024	0.7	.024
2000						
Storage	-	-	-	-	-	-
Treatment Plant	4.1	5.300	4.7	6.000	5.3	6.600
Intake & Pumping	4.1	.022	4.7	.025	5.3	.029
Diversion	-	-	-	-	-	-
Ground Water	1.2	.040	1.4	.050	1.6	.060
2020						
Storage	-	-	-	-	-	-
Treatment Plant	5.0	6.500	7.6	9.500	7.0	8.400
Intake & Pumping	4.7	.025	7.1	.038	6.5	.035
Diversion	-	-	-	-	-	-
Ground Water	1.4	.050	2.1	.070	2.0	.070

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The paper industry is the largest industrial water user in

Area 3, with a withdrawal of 45 m.g.d. The total withdrawal is 49 m.g.d., with food, fabrics and transportation using the remaining 4 m.g.d. All but 2 m.g.d. of the total withdrawal is self-supplied fresh water, which is developed from surface sources. There is no brackish or waste water industrial use.

Future Use

The paper industry will continue to be the dominant water-user in the Area, with a total withdrawal ranging from 72 m.g.d. for the 1980 EQ objective, to 177 m.g.d. for the 2020 RD objective. Additional industries with low water requirements that are expected to develop in the Area include leather, wood products, chemicals, glass and clay, metal products, machine equipment, electrical equipment and scientific instruments.

Table R-18 shows Area 3's present and projected industrial water requirements.

TABLE R-18
INDUSTRIAL WATER SUPPLY - AREA 3
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	49	47	2	0	0	3
1980						
EQ	80	78	2	0	0	4
NE	80	78	2	0	0	4
RD	83	80	3	0	0	4
2000						
EQ	126	121	5	0	0	7
NE	133	127	6	0	0	8
RD	141	135	6	0	0	8
2020						
EQ	177	168	9	0	0	11
NE	202	189	13	0	0	13
RD	223	212	11	0	0	14

Future Devices and Costs

The industrial water supply needs are currently met by river

and/or lake intakes and wells, and it is anticipated that future needs will continue to be satisfied in the same manner and in approximately the same proportion.

Devices that could satisfy the incremental increases in industrial water supply and their estimated costs are shown in Table R-19.

TABLE R-19
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 3
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Intake & Pumping	30	.20	30	.20	32	.20
Ground Water	1	.04	1	.04	1	.04
2000						
Intake & Pumping	41	.20	47	.20	53	.30
Ground Water	2	.07	2	.07	2	.07
2020						
Intake & Pumping	45	.20	59	.30	74	.40
Ground Water	2	.07	3	.10	3	.10

AREA 4. ANDROSCOGGIN RIVER BASIN

PUBLIC WATER

Present Use

In the allocation of counties to the particular Areas in the North Atlantic Region, Coos County in New Hampshire was assigned to Area 8. However, the major portion of the population of the county is actually in Area 4. In order to present a more realistic picture of the public water supply requirements for Area 4 it was decided to adjust Area populations by shifting some 29,000 people from Area 8 to Area 4. Adjustments were also made for population served and per capita income for the present and for the three bench mark years.

The total population of this Area is now 163,000 of which 149,000 people, or 92%, are served by the 24 central water supply systems in the Area. These systems which distribute an average of 14 m.g.d. of water obtain about 71% of their supply from surface sources, with the remaining 29% developed from ground water.

Future Use.

Population and per capita income have been projected to increase throughout the Study period under all three objectives. For example, under the NE and RD objectives, the total population and population served will increase to 220,000 and 207,000, respectively, by 2020. This represents respective growths of 35% and 40%. The per capita incomes differ according to objectives with the EQ per capita going from $2,327 to $10,694, the NE from $2,327 to $12,470, and the RD from $2,327 to $13,717. The public water supply requirements under the NE objective will increase from 14 m.g.d. at present, to 32 m.g.d. by the year 2020.

Present and projected public water supply requirements, total population, population served and per capita income for Area 4 are shown in Table R-20.

Future Devices and Costs

Additional storage facilities will be required by 1980 to satisfy a portion of the future public water supply needs through the year 2020. Rivers and/or lake intakes and pumping stations and well development will be required throughout the study period to supplement the water supplied from storage. Additional water treatment plant capacity will also be required throughout the Study period.

Table R-21 indicates the devices that could satisfy the incremental increases in public water supply needs and their estimated costs.

FIRGURE R-9

AREA 4 ANDROSCOGGIN RIVER BASIN

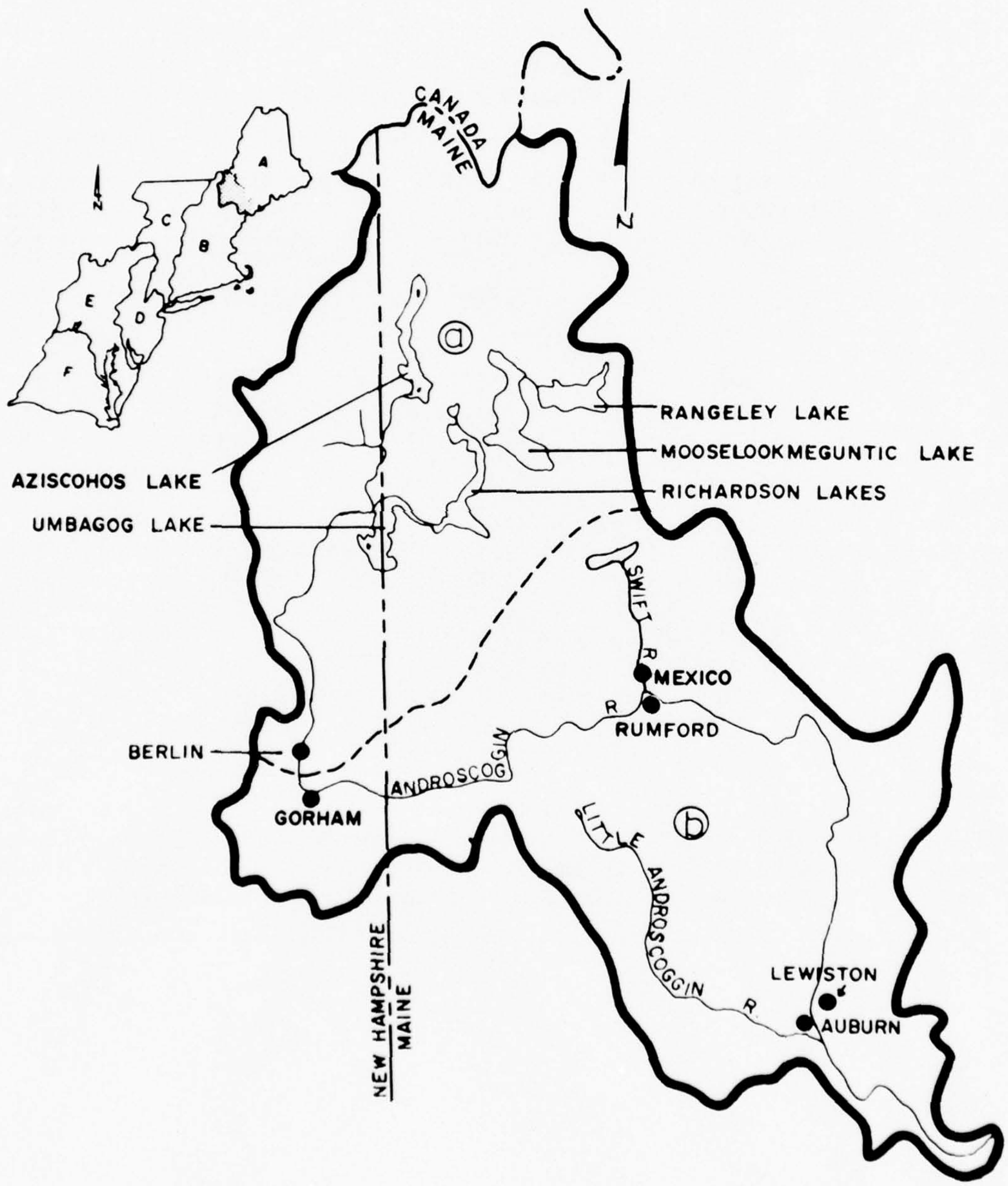


TABLE R-20
PUBLIC WATER SUPPLY - AREA 4

OBJECTIVE	TOTAL[1/] POPULATION (1,000s)	POPULATION[1/] SERVED (1,000s)	PER CAPITA[1/] INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	163	149	2,327	14
1980				
EQ	169	156	3,835	17
NE	175	161	4,030	18
RD	175	161	4,139	18
2000				
EQ	173	161	6,215	20
NE	188	175	6,912	23
RD	188	175	7,375	23
2020				
EQ	187	176	10,694	26
NE	220	207	12,470	32
RD	220	207	13,717	33

1/ Population and per capita income figures from Appendix B, Economic Base, were adjusted to reflect inclusion of a portion of Coos County, N.H., in Area 4. The figures for Area 8 have been adjusted accordingly.

TABLE R-21
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 4
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	2,000	1.200	3,300	2.000	3,300	2.000
Treatment Plant	1.8	2.000	2.5	3.000	2.5	3.000
Intake & Pumping	0.5	.003	0.8	.004	0.8	.004
Diversion	-	-	-	-	-	-
Ground Water	1.0	.040	1.7	.070	1.7	.070
2000						
Storage	-	-	-	-	-	-
Treatment Plant	1.1	1.300	1.9	2.000	1.9	2.000
Intake & Pumping	0.5	.003	0.9	.005	0.9	.005
Diversion	-	-	-	-	-	-
Ground Water	1.2	.050	2.0	.080	2.0	.080
2020						
Storage	-	-	-	-	-	-
Treatment Plant	1.3	1.400	3.7	3.000	4.2	3.600
Intake & Pumping	0.5	.003	1.5	.008	1.7	.009
Diversion	-	-	-	-	-	-
Ground Water	0.9	.030	2.7	.110	3.0	.120

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The Area's largest water-using industry is the paper industry, with a total intake of 74 m.g.d. The total industrial water withdrawal is 90 m.g.d., of which 87 m.g.d. are self-supplied. The chemicals, fabrics and food industries use 12 of the remaining 16 m.g.d. The bulk of the water for industrial use is from the surface sources. There is no brackish or waste water industrial use in the Area.

Future Use

Total industrial water intake will increase to 283 m.g.d.,

322 m.g.d. and 356 m.g.d. by 2020, under the EQ, NE and RD objectives. The paper industry will continue to be the major water user in the area with projected 2020 intakes of 193 m.g.d. (EQ), 217 m.g.d. (NE) and 241 m.g.d. (RD). Chemicals, fabrics and food will utilize about 70% of the remainder, with the balance spread among 10 low water-using industries.

Present and projected industrial water requirements are shown in Table R-22.

TABLE R-22
INDUSTRIAL WATER SUPPLY - AREA 4
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	90	87	3	0	0	4
1980						
EQ	139	135	4	0	0	8
NE	139	135	4	0	0	8
RD	143	138	5	0	0	8
2000						
EQ	210	202	8	0	0	10
NE	220	213	7	0	0	10
RD	236	227	9	0	0	12
2020						
EQ	283	271	12	0	0	15
NE	322	306	16	0	0	19
RD	356	341	15	0	0	21

Future Devices and Costs

River and/or lake intakes and ground water presently furnish the self-supplied industrial water requirements. It is anticipated that the future needs will be satisfied in the same fashion and in approximately the same proportion.

Devices that could furnish the incremental increases in industrial water needs and their estimated costs are shown in Table R-23.

TABLE R-23
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 4
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Intake & Pumping	46	.25	46	.25	49	.26
Ground Water	2	.08	2	.08	2	.08
2000						
Intake & Pumping	64	.35	74	.40	85	.46
Ground Water	3	.12	4	.16	4	.16
2020						
Intake & Pumping	66	.36	89	.48	109	.59
Ground Water	3	.12	4	.16	5	.20

AREA 5. MAINE COASTAL BASINS

PUBLIC WATER

Present Use

Area 5's total population is 162,000, of which 100,000, or 62%, receive their water supply from approximately 50 central water systems, which deliver an average of 13 m.g.d. Roughly 70% of the supply for these systems is developed from surface sources, including river intakes and small impoundments. The remainder is obtained from ground water.

Future Use

Public water supply requirements will continue to increase during the Study period, with the largest growth taking place during the final 20-year period. The requirements under the EQ objective are lower than either the NE or RD objective, with a 2020 figure of 28 m.g.d., as opposed to 33 m.g.d. for the other objectives. The population, population served and per capita income will also increase. For example, under the NE objective the population will increase from 162,000 to 240,000, the population served from 100,000 to 168,000, and the per capita income from \$2,036 to \$9,996.

Present and projected public water supply conditions for Area 5 are shown in Table R-24.

TABLE R-24
PUBLIC WATER SUPPLY - AREA 5

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	162	100	2,036	13
1980				
EQ	170	109	2,968	16
NE	175	113	3,120	16
RD	175	113	3,203	17
2000				
EQ	188	124	4,950	21
NE	205	136	5,508	23
RD	205	136	5,654	23
2020				
EQ	205	143	8,569	28
NE	240	168	9,996	33
RD	240	168	10,261	33

FIGURE R-10

AREA 5 MAINE COASTAL BASINS

Future Devices and Costs

The future public water supply needs can be met by providing additional reservoir storage for the 1980 and 2020 needs, and intake and pumping stations and ground water development for all time frames. Additional water treatment plant capacity will be needed throughout the Study period.

Devices needed to satisfy the incremental increases in public water supply needs and their estimated costs are shown in Table R-25.

TABLE R-25
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 5
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	5,800	1.600	5,800	1.600	7,700	2.200
Treatment Plant	2.6	2.400	2.6	2.400	3.5	3.200
Intake & Pumping	0.4	.002	0.4	.002	0.6	.003
Diversion	-	-	-	-	-	-
Ground Water	0.9	.140	0.9	.140	1.2	.190
2000						
Storage	-	-	-	-	-	-
Treatment Plant	2.4	2.200	3.3	3.900	2.8	3.700
Intake & Pumping	0.5	.003	0.7	.004	0.6	.003
Diversion	-	-	-	-	-	-
Ground Water	1.5	.240	2.2	.360	1.8	.290
2020						
Storage	630	0.400	880	0.600	880	0.600
Treatment Plant	4.1	5.300	5.9	6.000	5.9	6.000
Intake & Pumping	0.6	.003	0.9	.005	0.9	.005
Diversion	-	-	-	-	-	-
Ground Water	2.2	.360	3.1	.520	3.1	.520

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 5, is 72 m.g.d., of which 51 m.g.d. are self-supplied fresh water, 3 m.g.d. are publicly-supplied and 18 m.g.d. are brackish water. The paper and chemical industries are the two largest water users, with self-supplied fresh intakes of 27 m.g.d. and 19 m.g.d., respectively. The food industry uses 3 m.g.d. Brackish water use is divided almost equally between the paper and chemical industries. The self-supplied water is developed mainly from surface sources.

Future Use

The industrial water requirements will continue to grow throughout the Study period with 2020 total intakes of 364 m.g.d. for EQ, 410 m.g.d. for NE, and 457 m.g.d. for RD. The self-supplied fresh water needs will be 266 m.g.d. (EQ), 300 m.g.d. (NE), and 333 m.g.d. (RD).

The paper industry will continue to be the dominant self-supplied fresh water user, as shown in Table R-26.

TABLE R-26
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 5
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Paper	147	166	184
Chemicals	57	65	72
Food	20	23	25
Fabric	16	18	20
Glass	14	16	17

Brackish water intakes will be primarily for the paper and chemicals industries.

Area 5's present and projected industrial water requirements are shown in Table R-27.

TABLE R-27
INDUSTRIAL WATER SUPPLY - AREA 5
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	72	51	3	0	18	4
1980						
EQ	144	105	3	0	36	10
NE	144	105	3	0	36	10
RD	148	108	3	0	37	10
2000						
EQ	256	184	8	0	64	15
NE	270	195	7	0	68	17
RD	278	208	8	0	72	17
2020						
EQ	364	266	11	0	87	20
NE	410	300	11	0	99	25
RD	457	333	15	0	109	27

Future Devices and Costs

Industry in Area 5 utilizes both fresh and brackish water to satisfy the needs for self-supplied water. Rivers and/or lakes and ground water are the sources of the fresh, self-supplied water. Brackish water is obtained from the estuaries. It is anticipated that the future self-supplied industrial water needs will continue to be satisfied in the same manner and in approximately the same ratio.

Table R-28 shows devices needed for meeting the incremental increases in self-supplied industrial water and their estimated costs.

TABLE R-28
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 5
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	52	.28	52	.28	55	.30
Brackish Water						
Intake & Pumping	18	.10	18	.10	19	.10
Ground Water	2	.35	2	.35	2	.35
2000						
Fresh Water						
Intake & Pumping	76	.41	86	.46	96	.52
Brackish Water						
Intake & Pumping	28	.15	32	.17	35	.19
Ground Water	3	.51	4	.51	4	.51
2020						
Fresh Water						
Intake & Pumping	79	.43	101	.55	120	.65
Brackish Water						
Intake & Pumping	23	.12	31	.17	37	.20
Ground Water	3	.51	4	.68	5	.85

AREA 6. SOUTHERN MAINE AND COASTAL NEW HAMPSHIRE

PUBLIC WATER

Present Use

Approximately 400,000 people, or 82% of the Area 6's total population of 488,000, are supplied with water from 51 central water systems. These systems, which use surface sources for about 80% of their supply, distribute an average of 50 m.g.d. The remaining supply is developed from ground water.

Future Use

The factors influencing public water supply (population served and per capita income), will increase during the Study period for all three objectives. The 2020 public water supply requirements will be 119 m.g.d. (EQ), 143 m.g.d. (NE) and 145 m.g.d. (RD). Population served and per capita income under the NE objective, for example, will go to 834,000 and $12,029, respectively, by 2020.

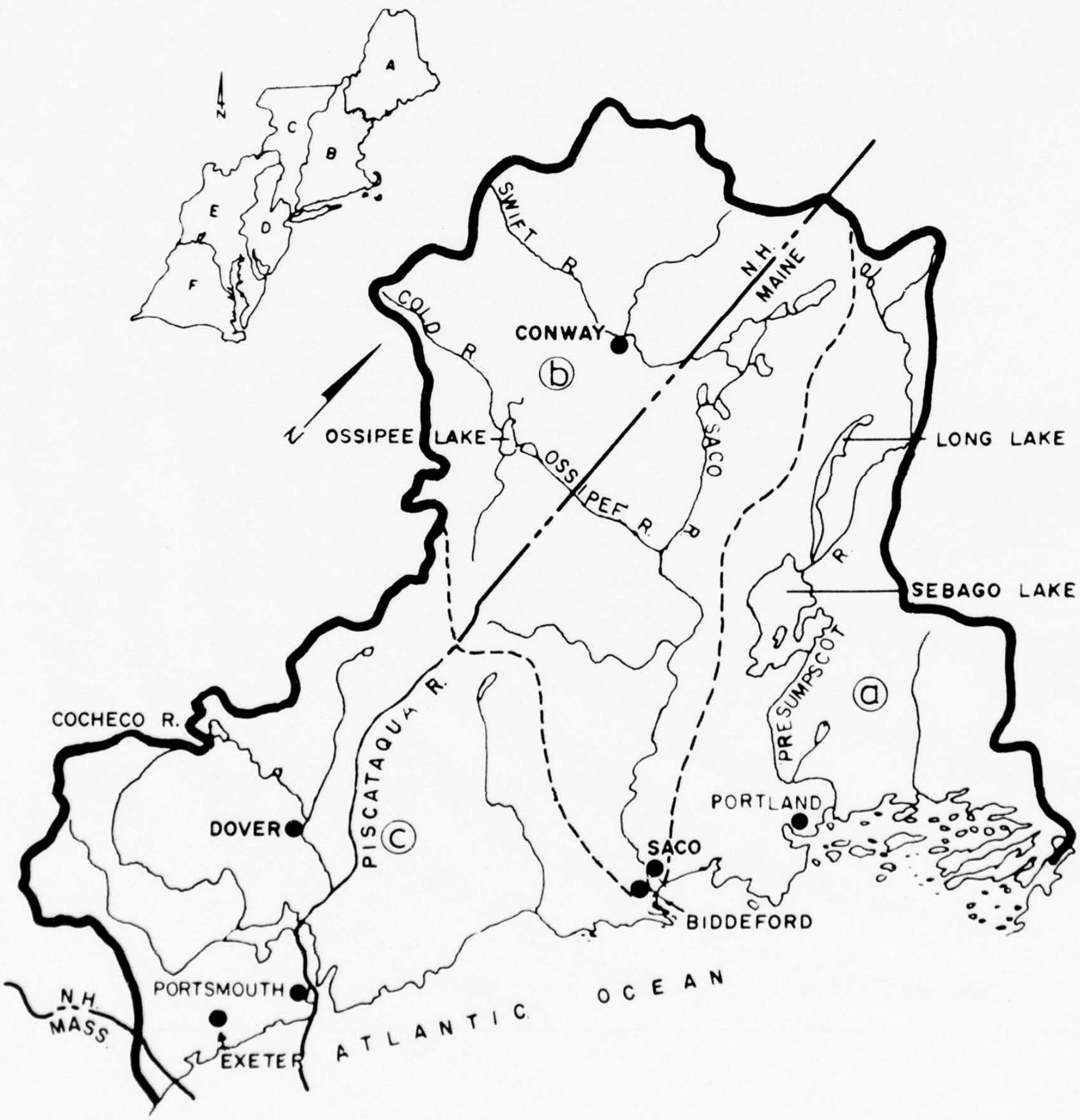
Area 6's present and projected public water supply conditions are shown in Table R-29.

TABLE R-29
PUBLIC WATER SUPPLY - AREA 6

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	488	399	2,530	50
1980				
EQ	560	471	3,654	63
NE	579	486	3,839	65
RD	579	486	3,943	66
2000				
EQ	674	579	6,038	86
NE	734	633	6,714	97
RD	734	633	6,896	98
2020				
EQ	781	711	10,316	119
NE	917	834	12,029	143
RD	917	834	12,354	145

FIGURE R-11

AREA 6 SOUTHERN MAINE AND COASTAL NEW HAMPSHIRE



Future Devices and Costs

The future public water supply needs can be met by providing additional reservoir storage, intakes and pumping stations and ground water development for all time frames of the Study period. Additional water treatment plant capacity will also be needed for all time frames.

Devices that could satisfy future public water supply needs and their estimated costs are shown in Table R-30.

TABLE R-30
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 6
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	3,900	1.200	4,500	1.400	4,800	1.500
Treatment Plant	1.6	1.900	1.9	2.000	2.0	2.000
Intake & Pumping	0.8	.004	1.0	.005	1.0	.005
Diversion	-	-	-	-	-	-
Ground Water	2.6	.120	3.0	.140	3.2	.150
2000						
Storage	6,000	1.500	8,300	2.100	8,300	2.100
Treatment Plant	3.5	3.000	4.8	3.200	4.8	3.200
Intake & Pumping	1.2	.007	1.6	.009	1.6	.009
Diversion	-	-	-	-	-	-
Ground Water	4.6	.220	6.4	.310	6.4	.310
2020						
Storage	3,400	.800	4,700	1.100	4,800	1.100
Treatment Plant	8.6	7.500	12.0	9.300	12.3	9.400
Intake & Pumping	2.3	.012	3.2	.017	3.3	.018
Diversion	-	-	-	-	-	-
Ground Water	6.6	.320	9.2	.440	9.4	.450

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

Area 6's total industrial water intake is 57 m.g.d., of which 45 m.g.d. are self-supplied fresh water, 1 m.g.d. are publicly-supplied and 11 m.g.d. are brackish water. The paper industry is the largest water user, with a self-supplied fresh intake of 31 m.g.d. The fabric, food, rubber and transportation industries use 9 m.g.d., and the food industry uses almost all of the brackish water.

Future Use

Industrial growth is reflected in the increased need for water supply. By 2020, the self-supplied fresh requirements will be 190 m.g.d. (EQ) 215 m.g.d (NE) and 236 m.g.d. (RD). Total intake will be 246 m.g.d. (EQ), 278 m.g.d. (NE) and 308 m.g.d. (RD).

The paper industry will continue to be the primary self-supplied fresh water user in the Area, as shown in Table R-31.

TABLE R-31
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 6
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Paper	95	107	119
Fabrics	21	24	27
Rubber	15	17	18
Food	12	14	15
Electrical Equipment	10	11	12

The remaining fresh self-supplied requirements are distributed over 11 other industries. Approximately 70% of the brackish water will be for the paper industry.

Table R-32 shows Area 6's present and projected industrial requirements.

Future Devices and Costs

River and/or lake water, wells and brackish water are used to satisfy the Area's self-supplied industrial water needs. It is anticipated that the future industrial water supply will be developed from the same sources and in approximately the same proportion.

TABLE R-32
INDUSTRIAL WATER SUPPLY - AREA 6
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	57	45	1	0	11	3
1980						
EQ	98	71	2	0	25	5
NE	98	71	2	0	25	5
RD	101	74	2	0	25	5
2000						
EQ	161	122	4	0	35	9
NE	168	131	4	0	33	9
RD	179	137	4	0	38	10
2020						
EQ	246	190	11	0	45	15
NE	278	215	11	0	52	18
RD	308	236	12	0	60	19

Table R-33 shows devices that could satisfy the increased self-supplied industrial water needs and the estimated costs of the facilities.

TABLE R-33
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 6
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water Intake & Pumping	25	.14	25	.14	28	.15
Brackish Water Intake & Pumping	14	.08	14	.08	14	.08
Ground Water	1	.07	1	.07	1	.07
2000						
Fresh Water Intake & Pumping	50	.27	59	.32	62	.33
Brackish Water Intake & Pumping	10	.05	8	.04	13	.07
Ground Water	1	.07	1	.07	1	.07
2020						
Fresh Water Intake & Pumping	66	.36	82	.44	97	.52
Brackish Water Intake & Pumping	10	.05	19	.10	22	.12
Ground Water	2	.10	2	.10	2	.10

AREA 7. MERRIMACK RIVER BASIN

PUBIC WATER

Present Use

The population figures for Area 7, as shown in Appendix B, Economic Base, include the New Hampshire counties of Belknap, Hillsborough and Merrimack, and the Massachusetts County of Worcester and 30% of Middlesex County.

In analyzing the water supply needs for the Area, it was felt that the county breakdown between Areas 7 and 9 did not represent a realistic picture of the populations of the two Areas. The following county population allocations and splits were made for Area 7 for the purpose of developing the Area's water supply needs: Belknap, Merrimack and Hillsborough Counties, New Hampshire - 100% in Area 7; Middlesex County, Mass. - 15% in Area 7 and 85% in Area 9; Worcester County, Mass. - 35% in Area 7, and 65% in Area 9; and Essex County, Mass. - 35% in Area 7, and 65% in Area 9. In conjunction with the population shifts, adjustments were also made for population served and per capita income. The total population of the Area is now 914,000, of which 858,000, or 94%, are served by 106 central water systems, which distribute an average of 106 m.g.d. Approximately 77% of the water supply for these systems is obtained from surface sources with the remainder derived from ground water.

Future Use

The projected public water supply requirements will increase throughout the Study period for all objectives, with the sharpest gain occurring in the 2000-2020 time span. Regional Development objective needs will be the largest in all bench mark years, and the needs for the EQ objective will be the lowest. The 2020 needs will be 280 m.g.d. (RD), 271 m.g.d. (NE) and 227 m.g.d. (EQ).

Population and per capita income will also increase during the Study period for all three objectives. For example, under the NE and RD objectives the population served will grow to 1,546,000 by 2020, and to 1,317,000 under the EQ objective; and per capita income will increase to $10,964 (EQ), $12,784 (NE) and $14,062 (RD).

Present and projected public water use, population, population served and per capita incomes for all objectives for all bench mark years are shown in Table R-34.

Future Devices and Costs

The future public water supply needs can be met by providing additional reservoir storage, intakes and pumping stations and

FIGURE R-12

AREA 7 MERRIMACK RIVER BASIN

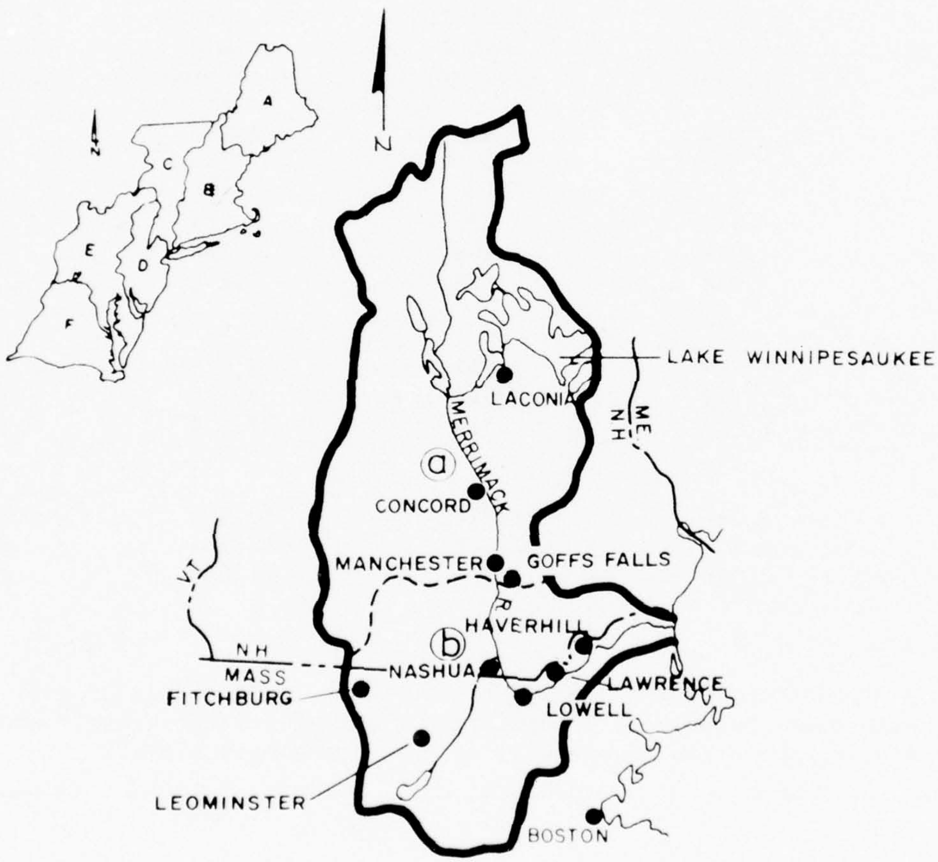


TABLE R-34
PUBLIC WATER SUPPLY - AREA 7

OBJECTIVE	TOTAL[1/] POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	914	858	2,857	106
1980				
EQ	975	926	4,125	126
NE	1,008	958	4,334	132
RD	1,008	958	4,451	133
2000				
EQ	1,182	1,147	6,673	173
NE	1,288	1,249	7,421	191
RD	1,288	1,249	7,918	195
2020				
EQ	1,344	1,317	10,964	227
NE	1,578	1,546	12,784	271
RD	1,578	1,546	14,062	280

1/ These population figures are lower than those presented in Appendix B, Economic Base, because of a population transfer between Areas 7 and 9. The Area 9 population figure will be correspondingly higher.

ground water development throughout the Study period. Additional water treatment plant capacity will be required for all time frames.

Devices that could satisfy the increased public water supply needs and their estimated costs are shown in Table R-35.

TABLE R-35
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 7
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	25,600	5.90	33,300	7.70	34,600	8.10
Treatment Plant	12.6	8.20	16.3	10.60	16.8	11.20
Intake & Pumping	5.1	.03	6.6	.04	6.8	.04
Diversion	-	-	-	-	-	-
Ground Water	4.5	.29	5.9	.36	6.1	.40
2000						
Storage	9,700	2.60	12,200	3.30	12,800	3.40
Treatment Plant	30.1	26.20	37.9	29.80	39.8	34.20
Intake & Pumping	19.0	.10	23.9	.13	25.1	.14
Diversion	-	-	-	-	-	-
Ground Water	10.6	.69	13.3	.87	14.0	.91
2020						
Storage	860	.70	1,280	1.00	1,360	1.10
Treatment Plant	21.7	26.40	32.2	39.00	34.2	41.40
Intake & Pumping	21.7	.12	32.2	.17	34.2	.19
Diversion	-	-	-	-	-	-
Ground Water	12.2	.81	18.1	1.20	19.2	1.27

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake for Area 7 is 85 m.g.d. of which 63 m.g.d. are self-supplied fresh water and the remaining 22 m.g.d. split between publicly-supplied fresh water and brackish water. The paper and chemical industries are the two major water users in the

Area with self-supplied fresh intakes of 20 and 19 m.g.d., respectively. The remaining 24 m.g.d. are spread over 12 industries with intakes no greater than 4 m.g.d.

Future Use

The projected growth of the Area throughout the Study period is reflected by the increased water demand by industry, with total intake requirements in 2020 of 347 m.g.d. (EQ), 391 m.g.d. (NE) and 432 m.g.d. (RD). The self-supplied fresh water needs are expected to be 260 m.g.d. (EQ), 295 m.g.d. (NE), and 323 m.g.d. (RD). Publicly-supplied fresh and brackish water will also increase, with respective 2020 needs of 49 m.g.d. and 38 m.g.d. (EQ), 54 m.g.d. and 42 m.g.d. (NE) and 61 m.g.d. and 48 m.g.d. (RD).

In 2020, it is projected that the paper industry will be the primary industrial user of self-supplied fresh water, as shown in Table R-36.

TABLE R-36
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 7
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Paper	61	69	76
Chemicals	38	43	47
Primary Metals	33	37	41
Fabrics	26	30	33
Rubber	17	19	21
Food	14	16	18
Electrical Equipment	13	15	17
Glass and Clay	13	15	16
Leather	8	9	10
Metal Products	8	9	10
Transportation Equipment	8	9	10

Area 7's present and projected industrial water requirements are shown in Table R-37.

TABLE R-37
INDUSTRIAL WATER SUPPLY - AREA 7
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	85	63	11	0	11	10
1980						
EQ	144	103	18	0	23	17
NE	144	103	20	0	21	17
RD	147	103	20	0	21	17
2000						
EQ	233	173	31	0	29	28
NE	248	181	33	0	34	30
RD	264	191	38	0	35	34
2020						
EQ	347	260	49	0	38	43
NE	391	295	54	0	42	50
RD	432	323	61	0	48	56

Future Devices and Costs

River and/or lake intakes, wells and brackish water furnish the water to meet the self-supplied industrial water needs in Area 7. It is anticipated that the future needs will be met in the same manner and in approximately the same proportion that now exists. Table R-38 indicates devices that could meet the incremental increases in self-supplied industrial water and their estimated costs.

TABLE R-38
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 7
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	36	.19	36	.19	39	.21
Brackish Water						
Intake & Pumping	12	.06	10	.05	10	.05
Ground Water	4	.27	4	.27	4	.27
2000						
Fresh Water						
Intake & Pumping	63	.34	71	.38	80	.43
Brackish Water						
Intake & Pumping	6	.03	13	.07	14	.08
Ground Water	7	.46	7	.46	8	.52
2020						
Fresh Water						
Intake & Pumping	79	.43	103	.56	119	.64
Brackish Water						
Intake & Pumping	9	.05	8	.04	13	.07
Ground Water	8	.52	11	.72	13	.85

AREA 8. CONNECTICUT RIVER BASIN

PUBLIC WATER

Present Use

The population, population served and per capita income for Area 8 were adjusted in accordance with the shift of population from Area 8 to Area 4, as discussed in the Area 4 Summary.

The total population of the Area is 1,679,000 people, of which 1,445,000, or 86%, are served from the 230 central water systems in the Area, which supply an average of 191 m.g.d. of water. Surface supplies account for approximately 83% of the water for the public systems, with the balance developed from ground water sources.

Future Use

Projected growth rate patterns should bring about increased public water supply requirements throughout the Study period. Projected requirements for 2020 are 433 m.g.d. (EQ), 517 m.g.d. (NE) and 533 m.g.d. (RD). There is a possibility that after 2000, some industrial water needs which would normally be self-supplied from surface sources may have to be satisfied from public water supplies. This may be necessary if surface supplies in the Area become limited.

The population served and per capita incomes will increase during the Study period for all three objectives. By 2020, the population served for the NE and RD objectives is expected to be 2,792,000, and 2,379,000 for the EQ objective. Per capita income has been projected to be $14,098 (RD) by 2020.

Present and projected public water use, population, population served and per capita incomes are shown in Table R-39.

Future Devices and Costs

The future public water supply needs in Area 8 can be met by providing additional reservoir storage, intakes and pumping stations and ground water development for all time frames of the Study period. Additional water treatment plant capacity will also be required throughout the Study period.

Devices that could satisfy the incremental increases in public water supply and the estimated costs of these facilities are shown in Table R-40.

FIGURE R-13

AREA 8 CONNECTICUT RIVER BASIN

TABLE R-39
PUBLIC WATER SUPPLY - AREA 8

OBJECTIVE	TOTAL 1/ POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	1,679	1,445	2,866	191
1980				
EQ	1,814	1,579	4,175	230
NE	1,876	1,632	4,387	240
RD	1,876	1,632	4,505	242
2000				
EQ	2,098	1,867	6,699	305
NE	2,286	2,034	7,450	338
RD	2,286	2,034	7,949	345
2020				
EQ	2,558	2,379	10,992	433
NE	3,002	2,792	12,817	517
RD	3,002	2,792	14,098	533

1/ Population figures from Appendix B, Economic Base, were decreased to reflect the transfer of a portion of the population of Coos County, N.H., to Area 4.

TABLE R-40
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 8
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	5,800	4.40	7,300	5.70	7,600	5.80
Treatment Plant	18.7	9.20	23.7	11.50	24.4	11.60
Intake & Pumping	3.7	.02	4.7	.03	4.8	.03
Diversion	-	-	-	-	-	-
Ground Water	6.7	.24	8.5	.31	8.8	.32
2000						
Storage	109,000	16.40	141,000	21.20	149,000	22.30
Treatment Plant	23.7	12.50	30.9	13.60	32.6	18.60
Intake & Pumping	7.4	.04	9.7	.05	10.2	.06
Diversion	-	-	-	-	-	-
Ground Water	13.0	.47	16.9	.61	17.8	.65
2020						
Storage	2,200	1.60	3,000	2.10	3,200	2.20
Treatment Plant	35.9	21.10	50.2	26.30	52.7	28.70
Intake & Pumping	10.3	.06	14.4	.08	15.1	.08
Diversion	-	-	-	-	-	-
Ground Water	21.8	.80	30.4	1.11	32.0	1.18

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake for Area 8 is 326 m.g.d., of which 289 m.g.d. are self-supplied, 36 m.g.d. are publicly-supplied and 1 m.g.d. are brackish. The paper and transportation equipment industries are the two major water users in the Area with self-supplied water intakes of 112 m.g.d. and 111 m.g.d., respectively. The chemicals, fabrics and metal products industries use 43 m.g.d. of the remaining 66 m.g.d., with the balance distributed among six other industries.

Future Use

The projected increase in industrial water supply requirements reflects the Area's anticipated growth. The total industrial water intake will increase by 2020 to 1,385 m.g.d. (EQ), 1,560 m.g.d. (NE) and 1,732 m.g.d. (RD), of which 1,244 m.g.d. (EQ), 1,401 m.g.d. (NE) and 1,553 m.g.d. (RD) will be self-supplied fresh water. Publicly-supplied industrial water will increase to 128 m.g.d. (EQ), 142 m.g.d. (NE) and 165 m.g.d. (RD) by 2020, and brackish water needs will be 13 m.g.d. (EQ), 17 m.g.d. (NE) and 20 m.g.d. (RD).

The transportation equipment and paper industries will continue to be the dominant industrial fresh water users in 2020, as shown in Table R-41.

TABLE R-41
2020 INDUSTRIAL TOTAL FRESH WATER REQUIREMENTS - AREA 8
(m.g.d.)

INDUSTRY	OBJECTIVE EQ	 NE	 RD
Transportation Equipment	616	693	768
Paper	363	408	453
Fabrics	111	126	139
Chemicals	74	83	92
Food	40	45	49
Machine Equipment	33	38	42
Electrical Equipment	32	36	40
Rubber	26	29	33
Primary Metals	23	26	30
Metal Products	20	22	25

Area 8's present and projected industrial water requirements are shown in Table R-42.

TABLE R-42
INDUSTRIAL WATER SUPPLY - AREA 8
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	326	289	36	0	1	16
1980						
EQ	519	463	49	0	7	31
NE	519	463	49	0	7	31
RD	532	475	52	0	5	31
2000						
EQ	874	779	85	0	10	52
NE	922	821	91	0	10	55
RD	984	877	95	0	12	59
2020						
EQ	1,385	1,244	128	0	13	76
NE	1,560	1,401	142	0	17	85
RD	1,732	1,553	165	0	20	94

Future Devices and Costs

Self-supplied industrial water needs are presently met by river and/or lake intakes, ground water and brackish water sources, and it is anticipated that future needs will be met in similar fashion. However, there is a strong possibility that, after the year 2000, surface water sources for industrial use may require regulation which will either limit withdrawals or require a cost-sharing by industry of the facilities needed to maintain minimum flows in the Area's rivers. While it can be assumed that cost-sharing may occur in the future, the determination of these costs is beyond the scope of the NAR study.

Table R-43 indicates devices that could satisfy the incremental increases in self-supplied industrial water and their estimated costs.

TABLE R-43
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 8
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	149	.80	149	.80	159	.86
Brackish Water						
Intake & Pumping	6	.03	6	.03	4	.02
Ground Water	25	.91	25	.91	27	.99
2000						
Fresh Water						
Intake & Pumping	270	1.46	306	1.65	344	1.86
Brackish Water						
Intake & Pumping	3	.02	3	.02	7	.04
Ground Water	46	1.74	52	1.97	58	2.20
2020						
Fresh Water						
Intake & Pumping	397	2.14	496	2.68	578	3.12
Brackish Water						
Intake & Pumping	3	.02	7	.04	8	.04
Ground Water	68	2.40	84	2.95	98	3.45

AREA 9. SOUTHEASTERN NEW ENGLAND

PUBLIC WATER

Present Use

The population, population served and per capita income for Area 9 were adjusted in accordance with the shift of population to Area 9 from Area 7 described in the Area 7 Summary.

The total population of Area 9 is 4,939,000 of which approximately 94%, or 4,798,000 people, were served from public water supply systems. The 230 central systems in the Area distributed an average of 617 m.g.d., with surface sources supplying about 74% of the water and ground water development the remaining 26%. Diversions from Area 8 (Connecticut River) and Area 7 (Merrimack River) provide almost half of the surface water supply in the Area.

Future Use

Public water supply requirements are expected to increase in conjunction with the Area's projected growth patterns. The 2000-2020 incremental increase in self-supplied industrial fresh water needs in the Area's northern portion has been shifted to public water supply. This transfer was made because it is expected that surface water resources will be insufficient to allow for private development after 2000.

Projected 2020 public supply requirements are 1,414 m.g.d. (EQ), 1,700 m.g.d. (NE) and 1,774 m.g.d. (RD). Of these, 96 m.g.d., 123 m.g.d. and 150 m.g.d., respectively, were transferred from projected industrial self-supplied fresh water needs, as noted in the preceding paragraph.

The population, population served and per capita income will increase during the Study period for all objectives. Under the NE and RD objectives, the population served in the Area is expected to be 8,620,000, and 7,345,000 under the EQ objective. It is anticipated that per capita income will increase to $11,035 (EQ), $12,867 (NE) and $14,154 (RD) by the year 2020.

The present and projected public water use, population, population served and per capita incomes are shown in Table R-44.

Future Devices and Costs

The future public water supply needs of Area 9 can be met by providing additional reservoir storage, intake and pumping stations and water treatment plants for each time frame of the Study period. Continued diversion from Area 8 (Connecticut River) is expected for

FIGURE R-14

AREA 9 SOUTHEASTERN NEW ENGLAND

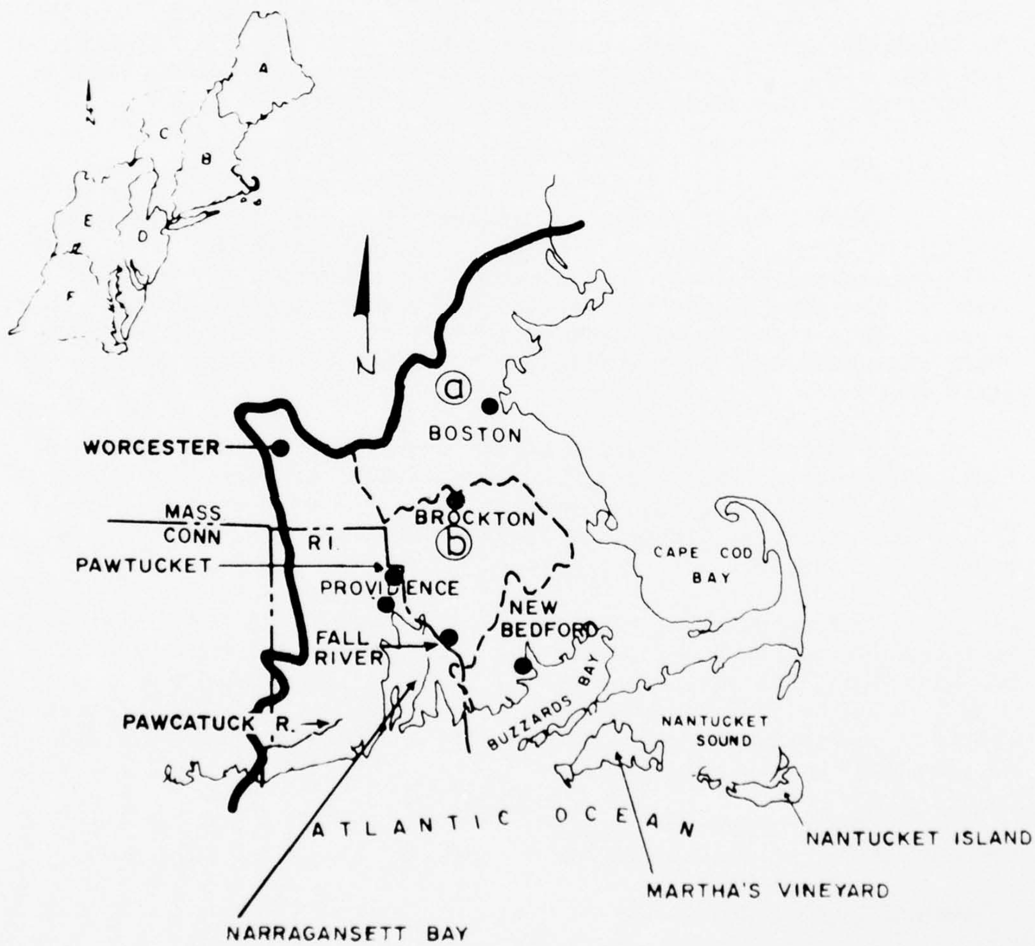


TABLE R-44
PUBLIC WATER SUPPLY - AREA 9

OBJECTIVE	TOTAL[1/] POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	4,939	4,798	2,913	617
1980				
EQ	5,551	5,440	4,163	762
NE	5,740	5,626	4,374	796
RD	5,740	5,626	4,492	802
2000				
EQ	6,507	6,377	6,730	1,006
NE	7,089	6,947	7,484	1,116
RD	7,089	6,947	7,985	1,130
2020				
EQ	7,419	7,345	11,035	1,414[2/]
NE	8,708	8,620	12,867	1,700[2/]
RD	8,708	8,620	14,154	1,774[2/]

1/ Appendix B, Economic Base, population figures were increased to reflect a population transfer from Area 7 to Area 9. Area 7 population figures are correspondingly lower.

2/ Includes the transfer of a portion of the self-supplied fresh water.

1980 and 2000. For 2020 it is anticipated that additional diversion from Area 7 (Merrimack River) will be needed. The storage shown in Table R-45 includes the storage necessary to maintain the diversion flows. Additional ground water development will be possible only through the year 2000 because the availability of ground water is limited.

Devices that could satisfy the incremental increases in public water supply and their estimated costs are shown in Table R-45.

TABLE R-45
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 9
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	145,000	33.00	179,000	40.80	185,000	42.10
Treatment Plant	58	12.90	72	14.40	74	14.60
Intake & Pumping	123	.66	150	.81	157	.85
Diversion	63	26.50	78	32.80	81	34.20
Ground Water	37	1.34	46	1.67	48	1.74
2000						
Storage	33,000	19.00	43,000	24.80	44,000	25.40
Treatment Plant	89	22.90	117	26.20	120	26.60
Intake & Pumping	244	1.32	320	1.73	328	1.77
Diversion	112	45.00	148	59.00	151	60.00
Ground Water	63	2.40	83	3.16	85	3.23
2020						
Storage	59,000	20.80	202,000	52.40	219,000	56.50
Treatment Plant	227	47.60	450	81.70	520	92.20
Intake & Pumping	206	1.11	434	2.34	503	2.72
Diversion	128	19.30	304	46.00	364	55.00
Ground Water	-	-	-	-	-	-

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

Area's 9's total industrial water intake is 322 m.g.d., of

which 170 m.g.d. are self-supplied, 58 m.g.d. are publicly-supplied and 94 m.g.d. are brackish. The chemical industry is the largest water user in the Area with a self-supplied intake of 69 m.g.d. The paper, fabric and primary metals industries use 27 m.g.d., 13 m.g.d. and 14 m.g.d., respectively, of the remaining 101 m.g.d., with the balance distributed among 10 other industries, none of which withdraws more then 10 m.g.d.

Future Use

The anticipated growth of Area 9 is generally reflected in the projected industrial water intake will increase to 1,244 m.g.d. (EQ), 1,400 m.g.d. (NE), and 1,552 m.g.d. (RD), and as covered in the Area 9 public water section, anticipated limitations on surface water supplies after 2000 will result in a shift of a portion of the self-supplied industrial water to publicly-supplied industrial water.

The paper, chemicals and primary metals industries will be the major industrial fresh water users in 2020, as shown in Table R-46.

TABLE R-46
2020 INDUSTRIAL TOTAL FRESH WATER REQUIREMENTS - AREA 9
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Primary Metals	171	192	214
Chemical	136	154	171
Paper	106	120	133
Machine Equipment	75	85	94
Fabrics	68	76	84
Electrical Equipment	66	76	84
Rubber	65	74	81
Metal Products	40	46	51
Transportation Equipment	39	44	49
Food	38	42	48
Scientific Instruments	25	28	32
Glass and Clay	23	26	28

The present and projected industrial water requirements for Area 9 are shown in Table R-47.

Future Devices and Costs

Area 9's self-supplied industrial water needs are presently

TABLE R-47
INDUSTRIAL WATER SUPPLY - AREA 9
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	322	170	58	0	94	47
1980						
EQ	522	269	92	0	161	79
NE	522	269	92	0	161	79
RD	534	278	95	0	161	80
2000						
EQ	840	436	158	0	246	126
NE	886	461	164	0	261	132
RD	944	492	177	0	275	143
2020						
EQ	1,244	557 1/	336 1/	0	351	187
NE	1,400	612 1/	396 1/	0	392	210
RD	1,552	666 1/	454 1/	0	432	236

1/ A portion of the 2020 self-supplied fresh water has been transferred to publicly-supplied fresh water.

satisfied by river and/or lake intakes, ground water and brackish water. Through the year 1980, it is likely that the future needs will be met in a similar fashion. By the year 2000, it is likely that the available ground water will not be able to entirely satisfy the projected ground water requirements. This would necessitate a shift of the unsatisfied ground water need to surface supplies. After the year 2000, surface water in the industrialized northern portion of the Area is expected to be limited so as to preclude additional development for private use. As a consequence, the incremental increase of fresh self-supplied industrial water for the period from 2000 to 2020 can be expected to be supplied from public water supply systems.

Devices that could satisfy the incremental increases in self-supplied industrial water supply and the estimated costs for these facilities are shown in Table R-48.

TABLE R-48
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 9
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	73	.39	73	.39	80	.43
Brackish Water						
Intake & Pumping	67	.36	67	.36	67	.36
Ground Water	26	1.06	26	1.06	28	1.12
2000						
Fresh Water						
Intake & Pumping	124	.67	171	.92	199	1.07
Brackish Water						
Intake & Pumping	85	.46	100	.54	114	.62
Ground Water	43	1.78	21	.87	15	.62
2020						
Fresh Water						
Intake & Pumping	121	.65	151	.82	174	.94
Brackish Water						
Intake & Pumping	105	.57	131	.71	157	.85
Ground Water	-	-	-	-	-	-

AREA 10. THAMES AND HOUSATONIC RIVER BASINS

PUBLIC WATER

Present Use

Approximately 1,719,000 people, or 83% of Area 10's total population of 2,062,000, receive their water supply from 190 central water supply systems. These systems deliver an average of 255 m.g.d., and depend upon surface sources for about 84% of their water, with the balance obtained from ground water development.

Future Use

Public water supply requirement projections will increase throughout the Study period, and in 2020 will be 640 m.g.d. (EQ), 763 m.g.d. (NE) and 769 m.g.d. (RD). There is a possibility that, after 2000, some industrial water needs, which normally would be self-supplied from surface sources, may have to be satisfied by public water systems.

The population served and per capita income will also increase during the Study period. Under the NE and RD objectives, the 2020 population served will be 3,840,000, and for the EQ objective, 3,287,000. Per capita income by 2020 can be expected to increase to $11,194 (EQ), $13,053 (NE) and $13,405 (RD).

The present and projected water use, population, population served and per capita income for Area 10 are shown in Table R-49.

Future Devices and Costs

The future public water supply needs of Area 10 can be satisfied by providing additional reservoir storage for 1980 and 2000. Ground water development, intakes and pumping stations and additional water treatment plant capacity will be required for all time frames of the Study period.

Devices that could satisfy the incremental increases in public water supply and the estimated costs for these facilities are shown in Table R-50.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake for Area 10 is 369 m.g.d. of which 94 m.g.d. is self-supplied, 42 m.g.d. is publicly-supplied and 233 m.g.d. is brackish. The primary metals, paper and chemical industries are the major water users in the Area with

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FIGURE R-15

AREA 10 THAMES AND HOUSATONIC RIVER BASINS

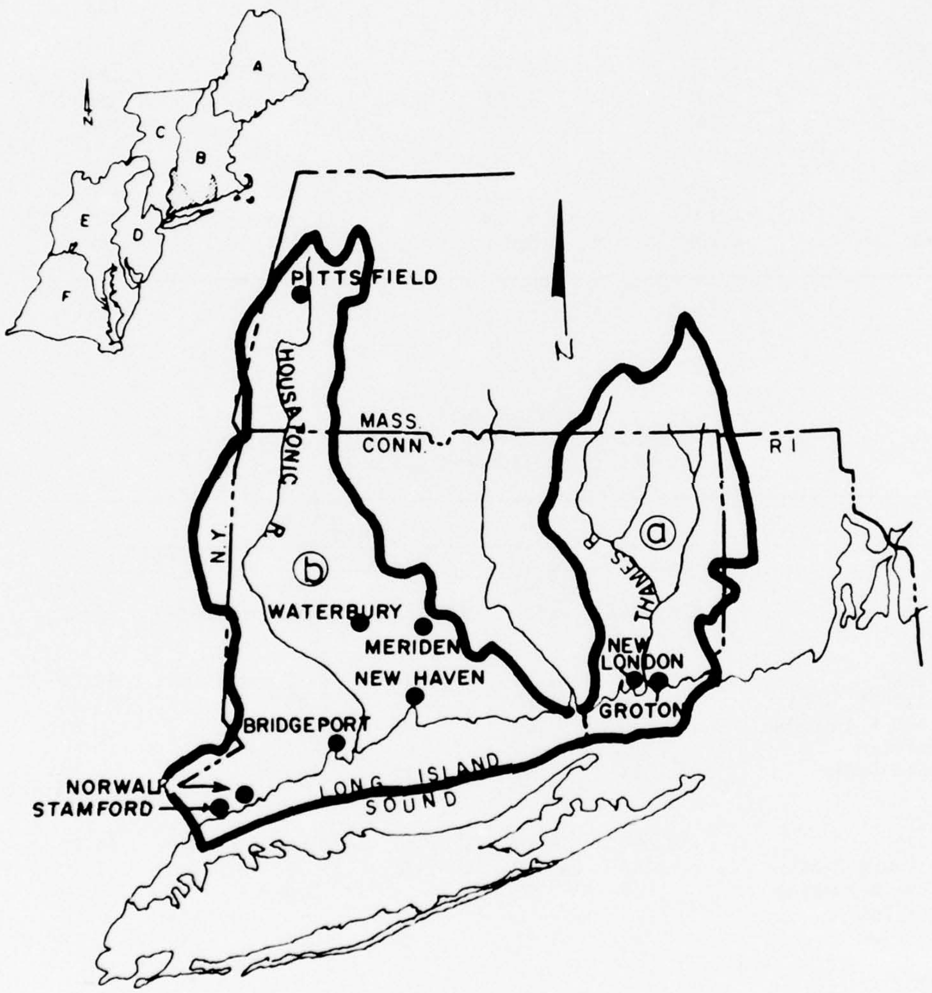


TABLE R-49
PUBLIC WATER SUPPLY - AREA 10

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	2,062	1,719	3,149	255
1980				
EQ	2,467	2,121	4,330	335
NE	2,551	2,195	4,550	349
RD	2,551	2,195	4,673	352
2000				
EQ	3,084	2,776	6,846	480
NE	3,360	3,008	7,613	529
RD	3,360	3,008	7,818	535
2020				
EQ	3,497	3,287	11,194	640
NE	4,105	3,840	13,053	763
RD	4,105	3,840	13,405	769

TABLE R-50
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 10
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	46,000	11.60	53,000	13.40	55,000	14.00
Treatment Plant	6	4.60	7	5.20	7	5.40
Intake & Pumping	2	.01	2	.01	2	.01
Diversion	-	-	-	-	-	-
Ground Water	13	.57	15	.66	16	.70
2000						
Storage	212,000	59.20	263,000	73.60	267,000	74.70
Treatment Plant	282	133.30	338	159.00	345	161.90
Intake & Pumping	4	.02	4	.02	5	.03
Diversion	-	-	-	-	-	-
Ground Water	23	1.01	29	1.28	29	1.28
2020						
Storage	-	-	-	-	-	-
Treatment Plant	21	11.90	31	16.40	31	16.40
Intake & Pumping	4	.02	6	.03	6	.03
Diversion	-	-	-	-	-	-
Ground Water	26	1.15	37	1.65	37	1.65

Note: Storage quantities in acre-feet; other devices in m.g.d.

self-supplied intakes of 31, 24 and 15 m.g.d., respectively. The remaining 24 m.g.d. are distributed among nine other industries, none of which uses more than 5 m.g.d. of self-supplied water. The chemical industry utilizes 201 of the total of 233 m.g.d. of brackish water.

Future Use

The increase in industrial water requirements is a reflection of the anticipated growth of Area 10 throughout the Study period. The total industrial water intake by 2020 is expected to be 1,199 m.g.d. (EQ), 1,350 m.g.d. (NE) and 1,500 m.g.d. (RD), of which 392 m.g.d. (EQ), 443 m.g.d. (NE) and 491 m.g.d. (RD) will be self-supplied fresh water. Publicly-supplied fresh water will increase to 167 m.g.d. (EQ), 190 m.g.d. (NE) and 210 m.g.d. (RD). Brackish water requirements will be 640 m.g.d. (EQ), 717 m.g.d. (NE) and 799 m.g.d. (RD).

In 2020, the major industrial water users are expected to be primary metals and paper, as shown in Table R-51.

TABLE R-51
2020 INDUSTRIAL TOTAL FRESH WATER REQUIREMENTS - AREA 10
(m.g.d.)

INDUSTRY	OBJECTIVE EQ	 NE	 RD
Primary Metals	160	180	199
Paper	123	139	154
Chemical	50	56	52
Machine Equipment	40	46	51
Electrical Equipment	39	44	49
Fabrics	35	39	43
Metal Products	24	27	30
Transportation Equipment	23	26	29
Rubber	21	24	26

Present and projected industrial water use in Area 10 is shown in Table R-52.

Future Devices and Costs

Self-supplied industrial water needs are presently met by river and/or lake intakes, wells and brackish water sources. It is anticipated that the future needs will be met in a similar fashion. There is a good possibility that after the year 2000, regulation may be imposed on surface water withdrawals for industrial use which would

TABLE R-52
INDUSTRIAL WATER SUPPLY - AREA 10
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	369	94	42	0	233	36
1980						
EQ	632	157	66	0	409	61
NE	632	157	66	0	409	61
RD	649	161	68	0	420	61
2000						
EQ	969	259	106	0	604	85
NE	1,025	274	112	0	639	101
RD	1,091	294	122	0	675	106
2020						
EQ	1,199	392	167	0	640	128
NE	1,350	443	190	0	717	147
RD	1,500	491	210	0	799	162

either limit the withdrawal, or require some form of cost-sharing by industry for facilities needed to maintain minimum flows in the rivers. While it is assumed that cost-sharing may occur in the future, the determination of these costs is beyond the scope of the NAR Study.

Table R-53 shows devices that could satisfy the incremental increases in self-supplied industrial water and their estimated costs.

TABLE R-53
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 10
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	42	.22	42	.22	45	.24
Brackish Water						
Intake & Pumping	176	.95	176	.95	187	1.01
Ground Water	21	.92	21	.92	22	.97
2000						
Fresh Water						
Intake & Pumping	68	.37	78	.42	89	.48
Brackish Water						
Intake & Pumping	195	1.05	230	1.24	255	1.38
Ground Water	34	1.52	39	1.72	44	1.96
2020						
Fresh Water						
Intake & Pumping	114	.62	145	.79	169	.91
Brackish Water						
Intake & Pumping	36	.19	78	.42	124	.67
Ground Water	19	.83	24	1.04	28	1.24

AREA 11. LAKE CHAMPLAIN AND ST. LAWRENCE RIVER DRAINAGE

PUBLIC WATER

Present Use

The total population of Area 11 is 533,000, of which 357,000, or about 67%, are supplied with water from 190 central water systems. These systems distribute an average of 51 m.g.d., of which about 70% is derived from surface sources with the balance developed from ground water.

Future Use

The public water supply requirements will increase throughout the Study period for all objectives, and by 2020 are expected to be 108 m.g.d. (EQ), 136 m.g.d. (NE), and 137 m.g.d. (RD). Population served and per capita income will also rise, and in 2020, the population served for the NE and RD objectives will be 633,000, and 520,000 for the EQ objective. Per capita income will grow to $10,038 (EQ), $11,261 (NE), and $12,020 (RD).

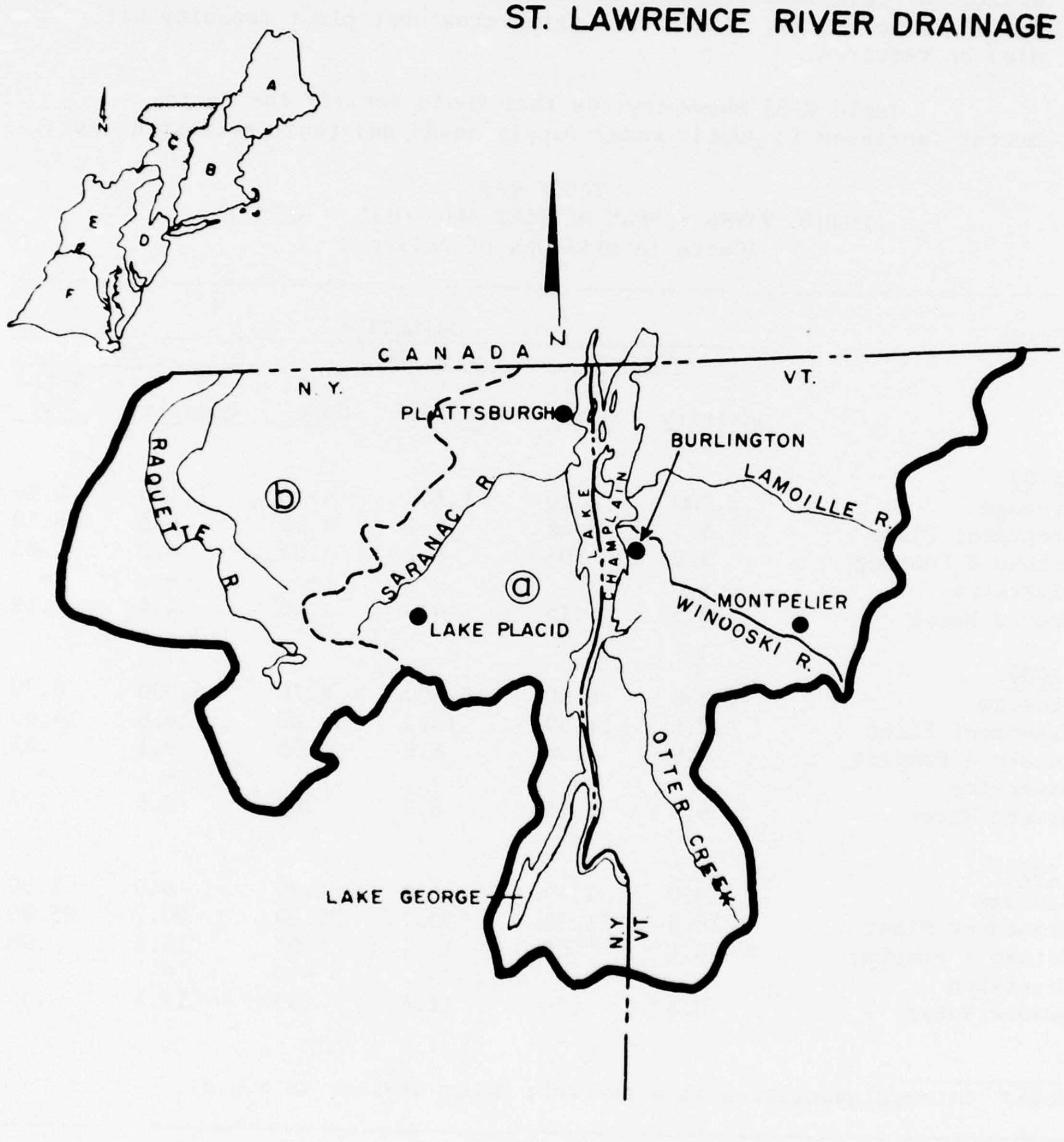
Present and projected water requirements population, population served and per capita income for Area 11 are shown in Table R-54.

TABLE R-54
PUBLIC WATER SUPPLY - AREA 11

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	533	357	2,217	51
1980				
EQ	568	404	3,260	63
NE	588	415	3,426	66
RD	588	415	3,518	66
2000				
EQ	621	472	5,571	85
NE	677	515	6,195	94
RD	677	515	6,362	95
2020				
EQ	650	520	10,038	108
NE	793	633	11,261	136
RD	793	633	12,020	137

FIGURE R-16

AREA II LAKE CHAMPLAIN AND ST. LAWRENCE RIVER DRAINAGE



Future Devices and Costs

Future public water supply needs can be met by providing additional reservoir storage, intakes and pumping stations and wells for all time frames. Additional water treatment plant capacity will also be required.

Table R-55 shows devices that could satisfy the incremental increases in public water supply needs and their estimated costs.

TABLE R-55
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 11
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	1,100	3.20	1,100	4.10	1,100	4.10
Treatment Plant	5.5	6.60	6.7	8.50	6.8	8.50
Intake & Pumping	5.0	.03	6.2	.03	6.2	.03
Diversion	-	-	-	-	-	-
Ground Water	3.5	.15	4.4	.19	4.4	.19
2000						
Storage	4,200	6.80	5,400	8.70	5,600	8.70
Treatment Plant	12.6	11.60	16.1	14.30	16.6	14.60
Intake & Pumping	6.9	.04	8.8	.05	9.1	.05
Diversion	-	-	-	-	-	-
Ground Water	6.5	.29	8.2	.63	8.5	.38
2020						
Storage	350	1.10	640	1.90	640	1.90
Treatment Plant	16.8	15.30	30.7	25.00	30.7	25.00
Intake & Pumping	8.4	.05	15.4	.08	15.4	.08
Diversion	-	-	-	-	-	-
Ground Water	6.8	.30	12.4	.55	12.4	.55

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 11 is 104 m.g.d.,

of which 99 m.g.d. are self-supplied and 5 m.g.d. are publicly-supplied. There is no brackish water use. The paper (49 m.g.d.) and primary metals (44 m.g.d.) industries are the major water users. The remaining 6 m.g.d. are equally divided among the food, chemicals, and glass and clay industries.

Future Use

There is a steady increase projected for industrial water requirements in Area 11 for all objectives, though perhaps not as sharp as in some of the other NAR Areas. The total intake will be 323 m.g.d. (EQ), 365 m.g.d. (NE) and 405 m.g.d. (RD), of which the respective self-supplied fresh water needs are expected to be 302 m.g.d., 341 m.g.d. and 377 m.g.d.

The primary metals and paper industries will be the principal self-supplied fresh water users in 2020, as shown in Table R-56.

TABLE R-56
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 11
(m.g.d.)

		OBJECTIVE	
INDUSTRY	EQ	NE	RD
Primary Metals	133	150	166
Paper	119	134	148
Glass and Clay	21	24	26
Food	6	12	13

Table R-57 shows Area 11's present and projected industrial water requirements.

Future Devices and Costs

River and/or lake intakes and wells presently furnish the water to meet the self-supplied industrial needs of the Area, and it is expected that future needs will be met in the same fashion and proportion.

Devices that could satisfy the incremental increases in self-supplied industrial water needs and their estimated costs are shown in Table R-58.

TABLE R-57
INDUSTRIAL WATER SUPPLY - AREA 11
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	104	99	5	0	0	9
1980						
EQ	158	149	9	0	0	15
NE	158	149	9	0	0	15
RD	162	153	9	0	0	16
2000						
EQ	236	221	15	0	0	22
NE	250	236	14	0	0	24
RD	265	250	15	0	0	25
2020						
EQ	323	302	21	0	0	33
NE	365	341	24	0	0	36
RD	405	377	28	0	0	40

TABLE R-58
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 11
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	43	.23	43	.23	47	.25
Brackish Water						
Intake & Pumping	-	-	-	-	-	-
Ground Water	7	.31	7	.31	7	.31
2000						
Fresh Water						
Intake & Pumping	63	.34	76	.41	84	.45
Brackish Water						
Intake & Pumping	-	-	-	-	-	-
Ground Water	9	.40	11	.49	13	.58
2020						
Fresh Water						
Intake & Pumping	70	.38	91	.49	110	.59
Brackish Water						
Intake & Pumping	-	-	-	-	-	-
Ground Water	11	.49	14	.63	17	.76

AREA 12. HUDSON RIVER BASIN

PUBLIC WATER

Present Use

The total population of Area 12 is 2,136,000, of which 1,557,000, or roughly 73%, are connected to 300 central water supply systems. These central systems distribute an average of 226 m.g.d., of which about 73% is from surface sources, with the remaining 27% developed from ground water supplies.

Future Use

The projected public water supply requirements are expected to increase throughout the Study period for all objectives. The 2020 requirements will be 679 m.g.d. (EQ), 820 m.g.d. (NE) and 822 m.g.d. (RD). There is a possibility that after the year 2000, some of the industrial water supply needs which would normally be self-supplied from surface sources may have to be satisfied from the public water supply. This shift would occur if the surface supplies in the Area become limited.

The population served will grow to 4,583,000 under the NE and RD objectives, and 3,886,000 under the EQ objective. Per capita income is expected to increase to $11,612 (EQ), $13,540 (NE) and $13,906 (RD).

The present and projected public water supply requirements, population, population served and per capita income for Area 12 are shown in Table R-59.

Future Devices and Costs

The future public water supply needs of Area 12 can be satisfied by providing additional reservoir storage, intakes and pumping stations, ground water development and water treatment plant capacity for all time frames of the Study period.

Devices that could satisfy the incremental increases in public water supply and the estimated costs for these facilities are shown in Table R-60.

SELF-SUPPLIED INDUSTRIAL

Present Use

The total industrial water intake in Area 12 is 315 m.g.d., of which 280 m.g.d. are self-supplied, 24 m.g.d. are publicly-supplied and 11 m.g.d. are brackish. The paper, primary metals and chemical

FIGURE R-17

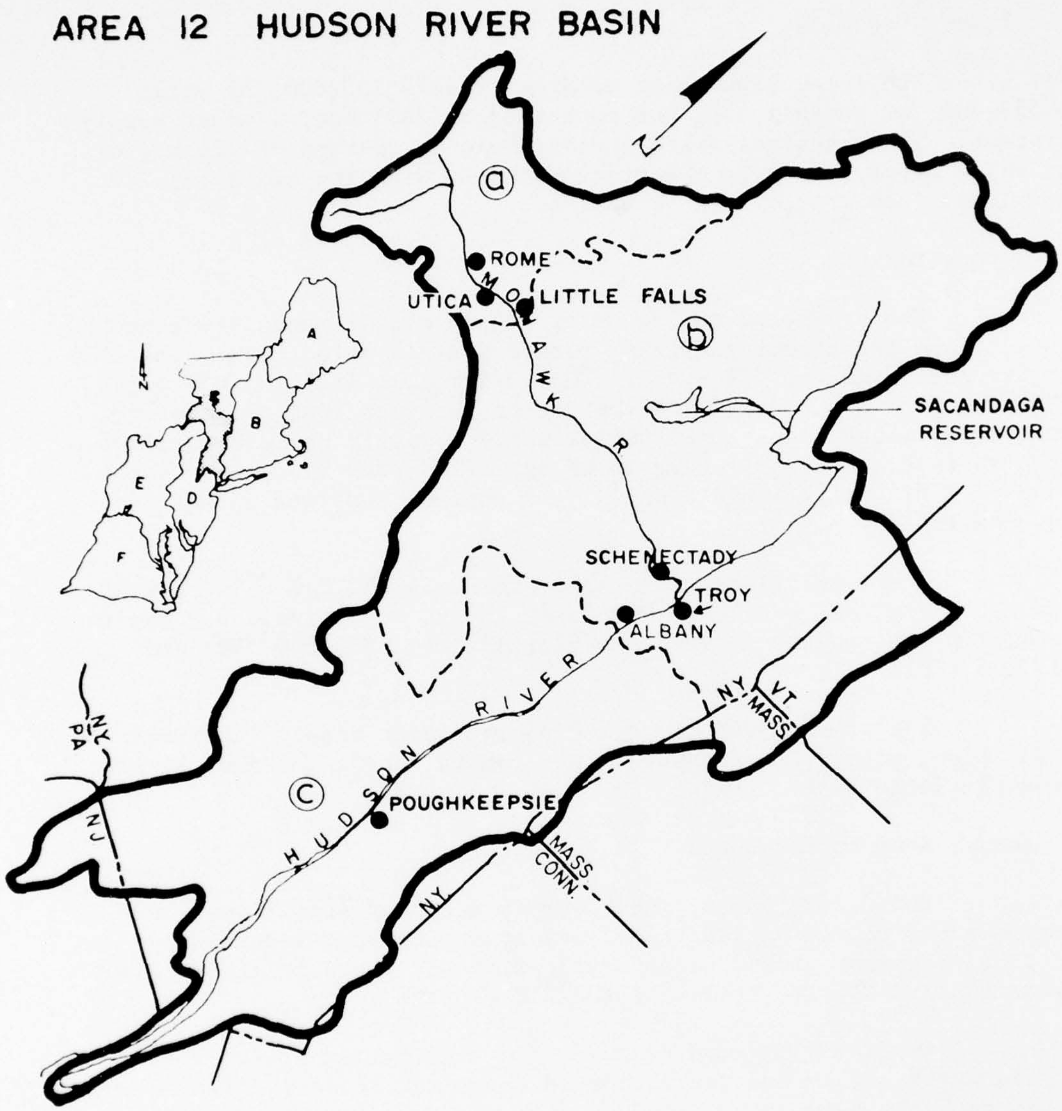

AREA 12 HUDSON RIVER BASIN
N
a
ROME
UTICA
LITTLE FALLS
MOHAWK R
b
SACANDAGA
RESERVOIR
SCHENECTADY
TROY
ALBANY
HUDSON RIVER
NY
VT
MASS
NY
PA
NJ
c
POUGHKEEPSIE
MASS
CONN.
NY
A
B
D
E
F

TABLE R-59
PUBLIC WATER SUPPLY - AREA 12

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	2,136	1,557	2,811	226
1980				
EQ	2,555	1,942	4,257	300
NE	2,643	2,021	4,473	315
RD	2,643	2,021	4,594	317
2000				
EQ	3,371	2,764	7,018	453
NE	3,672	3,028	7,798	505
RD	3,672	3,028	8,008	520
2020				
EQ	4,318	3,886	11,612	679
NE	5,068	4,583	13,540	820
RD	5,068	4,583	13,906	822

TABLE R-60
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 12
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	104,000	61.50	126,000	74.90	126,000	74.90
Treatment Plant	31	27.10	38	31.10	38	32.70
Intake & Pumping	17	.09	21	.11	21	.11
Diversion	-	-	-	-	-	-
Ground Water	15	.58	17	.66	18	.70
2000						
Storage	39,500	32.90	48,000	39.90	51,000	42.50
Treatment Plant	81	65.80	100	80.30	107	85.50
Intake & Pumping	44	.24	54	.29	58	.31
Diversion	-	-	-	-	-	-
Ground Water	31	1.23	39	1.59	41	1.69
2020						
Storage	3,100	5.00	4,400	7.10	4,200	6.80
Treatment Plant	166	103.20	231	148.10	221	133.50
Intake & Pumping	67	.36	93	.50	89	.48
Diversion	-	-	-	-	-	-
Ground Water	44	1.79	62	2.67	59	2.54

Note: Storage quantities in acre-feet; other devices in m.g.d.

industries are the major water users in the area with self-supplied fresh uses of 103, 91, and 55 m.g.d., respectively. The remaining 31 m.g.d. are distributed among nine other industries, none of which has a use exceeding 10 m.g.d. The chemical industry has a brackish intake of 7 m.g.d.

Future Use

The projected growth for Area 12 is reflected in the increased industrial water supply requirements for all objectives and target years. The total industrial water intake by 2020 is expected to be 1,336 m.g.d. (EQ), 1,505 m.g.d. (NE) and 1,668 m.g.d. (RD), of which 1,220 m.g.d. (EQ), 1,336 m.g.d. (NE) and 1,521 m.g.d. (RD) will be self-supplied fresh water. Publicly-supplied fresh water will be 84 m.g.d. (EQ), 101 m.g.d. (NE) and 105 m.g.d. (RD). Brackish water requirements will be 32 m.g.d. (EQ), 38 m.g.d. (NE) and 42 m.g.d. (RD) in 2020.

The projected major industrial fresh water users for 2020 are the primary metals, paper and chemicals industries, as shown in Table R-61.

TABLE R-61
2020 INDUSTRIAL TOTAL FRESH WATER REQUIREMENTS - AREA 12
(m.g.d.)

	OBJECTIVE		
INDUSTRIAL	EQ	NE	RD
Primary Metals	711	800	888
Paper	208	234	259
Chemicals	153	172	191
Glass and Clay	55	62	69
Food	54	61	67
Fabrics	28	31	34
Electrical Equipment	23	26	30
Metal Products	14	15	18
Transportation Equipment	14	15	17
Leather	11	12	13

Area 12's present and projected industrial water requirements are shown in Table R-62.

Future Devices and Costs

Self-supplied industrial water needs in Area 12 are presently met by river and/or lake intakes, ground water and brackish water

TABLE R-62
INDUSTRIAL WATER SUPPLY - AREA 12
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	315	280	24	0	11	29
1980						
EQ	529	471	41	0	17	54
NE	529	471	41	0	17	54
RD	543	483	42	0	18	56
2000						
EQ	875	788	62	0	25	97
NE	927	833	68	0	26	101
RD	986	888	70	0	28	107
2020						
EQ	1,336	1,220	84	0	32	146
NE	1,505	1,366	101	0	38	172
RD	1,668	1,521	105	0	42	194

sources, and it is expected that future needs will be met in similar fashion. There is a good possibility that after the year 2000 regulation may be imposed on surface water withdrawals for industrial use. This regulation would either limit the withdrawal or require some form of cost-sharing by industry for the facilities needed to maintain minimum flows in the Area's rivers. While it can be assumed that cost-sharing may occur in the future, the determination of these costs is beyond the scope of the NAR study.

Table R-63 indicates devices that could satisfy the future self-supplied industrial water supply and the estimated costs for these facilities.

TABLE R-63
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 12
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	172	.93	172	.93	183	.99
Brackish Water						
Intake & Pumping	6	.03	6	.03	7	.04
Ground Water	19	.74	19	.74	20	.78
2000						
Fresh Water						
Intake & Pumping	285	1.54	326	1.76	364	1.97
Brackish Water						
Intake & Pumping	8	.04	9	.05	10	.05
Ground Water	32	1.27	36	1.46	41	1.69
2020						
Fresh Water						
Intake & Pumping	389	2.10	484	2.61	570	3.08
Brackish Water						
Intake & Pumping	7	.04	12	.06	14	.08
Ground Water	43	1.74	54	2.32	63	2.72

AREA 13. SOUTHEASTERN NEW YORK METROPOLITAN AREA

PUBLIC WATER

Present Use

Area 13's total population is 11,083,000, 97% of which, or 10,708,000 people, are connected to 110 central water supply systems, which distribute in 1965 an average of 1,404 m.g.d. Approximately 75% of this total is derived from surface sources and the remaining 25% developed from ground water supplies. Diversions from Area 12 (Hudson River) and Area 15 (Delaware River) provide the bulk of the surface water supply in the Area.

Future Use

The projected water supply requirements are expected to increase during the Study period for all objectives, and by 2020 are expected to be 2,469 m.g.d. (EQ) 2,954 m.g.d. (NE), and 2,978 m.g.d. (RD). The population served and per capita income will also increase, and in 2020 the population served under the NE and RD objectives is expected to be 15,335,000, and 13,065,000 for the EQ objective. The 2020 per capita incomes are projected to be $12,569 (EQ), $14,655 (NE) and $15,051 (RD).

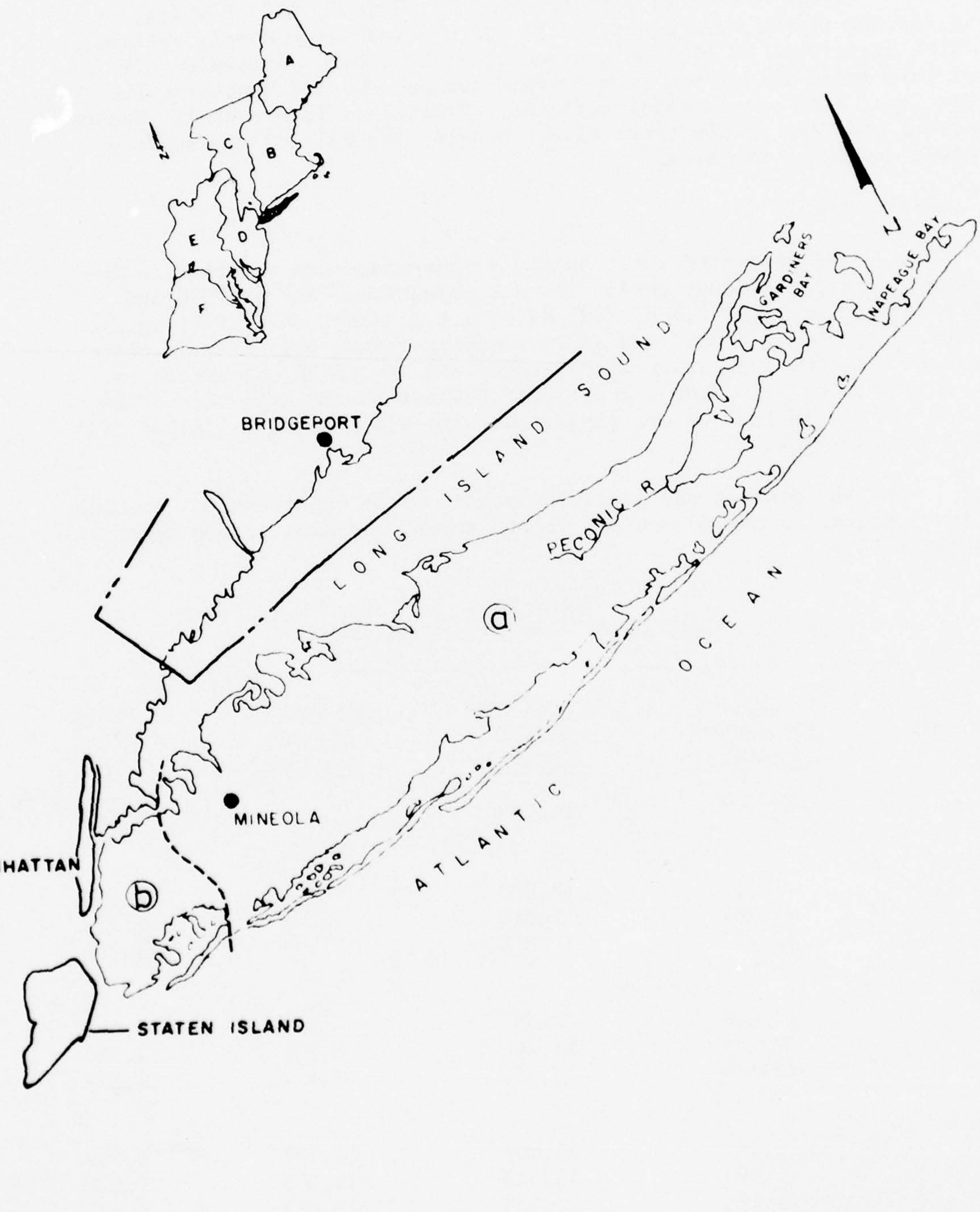
The present and projected public water requirements, population, population served and per capita income for Area 13 are shown in Table R-64.

TABLE R-64
PUBLIC WATER SUPPLY - AREA 13

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	11,083	10,708	3,521	1,404
1980				
EQ	11,837	11,482	4,896	1,654
NE	12,241	11,830	5,144	1,722
RD	12,241	11,830	5,283	1,735
2000				
EQ	12,648	12,395	7,856	2,042
NE	13,778	13,466	8,736	2,260
RD	13,778	13,466	8,972	2,279
2020				
EQ	13,197	13,065	12,569	2,469
NE	15,490	15,335	14,655	2,954
RD	15,490	15,335	15,051	2,978

FIGURE R-18

AREA 13 SOUTHEASTERN NEW YORK METROPOLITAN AREA



Future Devices and Costs

Area 13's future public water supply needs can be met by providing for additional storage by the year 2020. Additional diversion from Area 12 (Hudson River) is expected to be required to satisfy the 2000 and 2020 needs. Intake and pumping stations, wells and additional water treatment plant capacity will be needed for all time frames of the Study period. Groundwater management programs are under study including recharge with treated sewage effluent.

Devices that could satisfy the incremental increase in public water supply, including storage necessary to maintain diversion flows, and the estimated costs for these facilities are shown in Table R-65.

TABLE R-65
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 13
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	4	4.20	5	5.40	5	6.00
Intake & Pumping	4	.02	5	.03	5	.03
Diversion	-	-	-	-	-	-
Ground Water	63	1.25	80	1.59	83	1.65
2000						
Storage	476,000	51.90	660,000	70.80	668,000	72.50
Treatment Plant	223	44.30	309	61.60	311	62.40
Intake & Pumping	223	1.20	309	1.66	311	1.68
Diversion	216	121.00	300	137.00	302	137.00
Ground Water	97	1.93	135	2.69	137	2.73
2020						
Storage	-	-	-	-	-	-
Treatment Plant	345	67.20	562	108.50	566	110.00
Intake & Pumping	345	1.86	562	3.04	566	3.06
Diversion	337	137.00	548	172.00	552	172.00
Ground Water	107	2.13	174	3.62	175	3.64

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

Area 13's total industrial water intake is 276 m.g.d., of which 13 m.g.d. are self-supplied, 90 m.g.d. are publicly-supplied and 173 m.g.d. are brackish. Self-supplied industrial water is low in this Area with the three largest users, transportation equipment, electrical equipment and metal products, utilizing 5 m.g.d., 3 m.g.d. and 2 m.g.d., respectively. Brackish water is used extensively in the Area, with the chemicals, food, petroleum and primary metals industries the major users.

Future Use

While the total quantity of industrial water intake will increase considerably during the Study period, the self-supplied fresh water intake will be a fairly low percentage of the total intake. The total intake in 2020 is expected to 1,113 m.g.d. (EQ), 1,260 m.g.d. (NE) and 1,397 m.g.d. (RD), while the self-supplied industrial water will be 73 m.g.d. (EQ), 82 m.g.d. (NE) and 93 m.g.d. (RD). Brackish water will constitute the largest part of the total intake with projected intakes of 621 m.g.d. (EQ), 700 m.g.d. (NE) and 778 m.g.d. (RD).

The largest self-supplied fresh water-using industries in 2020 are shown in Table R-66.

TABLE R-66
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 13
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Electrical Equipment	20	23	25
Metal Products	12	14	15
Transportation Equipment	12	13	15
Scientific Instruments	8	9	10

Area 13's present and projected industrial water requirements are shown in Table R-67.

Future Devices and Costs

Self-supplied industrial water requirements in Area 13 are

TABLE R-67
INDUSTRIAL WATER SUPPLY - AREA 13
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	276	13	90	0	173	18
1980						
EQ	421	21	126	0	274	33
NE	421	21	126	0	274	33
RD	430	22	126	0	282	34
2000						
EQ	693	40	229	0	424	58
NE	731	43	243	0	445	60
RD	780	45	262	0	473	65
2020						
EQ	1,113	73	419	0	621	103
NE	1,260	82	478	0	700	119
RD	1,397	93	526	0	778	128

presently met by ground water and brackish water sources. It is anticipated that the future needs will be satisfied in a similar fashion.

Table R-68 shows devices that could satisfy the incremental increase in self-supplied industrial water and their estimated costs.

TABLE R-68
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 13
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	-	-	-	-	-	-
Brackish Water						
Intake & Pumping	101	.55	101	.55	109	.59
Ground Water	8	.16	8	.16	9	.18
2000						
Fresh Water						
Intake & Pumping	-	-	-	-	-	-
Brackish Water						
Intake & Pumping	150	.81	171	.92	191	1.03
Ground Water	19	.38	22	.44	23	.46
2020						
Fresh Water						
Intake & Pumping	-	-	-	-	-	-
Brackish Water						
Intake & Pumping	197	1.06	255	1.38	305	1.65
Ground Water	33	.66	39	.78	48	.95

AREA 14. NORTHERN NEW JERSEY

PUBLIC WATER

Present Use

The total population of Area 14 is 4,387,000, of which about 94%, or 4,124,000 people, are connected to central water supply systems. These 180 central systems distribute an average of 513 m.g.d., and obtain approximately 76% of their supply from surface sources, with the remainder developed from ground water supplies. Diversion from Area 15 (Delaware River) accounts for a small portion of the surface water supply in the Area.

Future Use.

The projected public water requirements for Area 14 will increase through 2020 for all three objectives. In addition to the normal increase resulting from growth in the population served and per capita income, the 2000 and 2020 public water requirements have been increased by the addition of the 1980-2000 and 2000-2020 increments of self-supplied industrial fresh water. This transfer was made because it is felt that the Area's available water resources will be so limited that private development and use will not be feasible.

The projected public water supply requirements for 2000 will be 1,096 m.g.d. (EQ), 1,231 m.g.d. (NE) and 1277 m.g.d. (RD), of which 209, 248 and 286 m.g.d., respectively, represent the shift of self-supplied industrial water. Similarly the 2020 public water requirement will be 1,678 m.g.d. (EQ), 2,016 m.g.d. (NE) and 2,133 m.g.d. (RD), of which 506, 609 and 714 m.g.d. are the respective amounts of self-supplied industrial water transfered to the public supply.

The population served in 2020 is expected to be 6,965,000 (EQ), 8,208,000 (NE & RD). Per capita income has been projected to increase by 2020 to $12,513 (EQ), $14,591 (NE) and $14,984 (RD).

Present and projected public water supply requirements, population, population served and per capita income for Area 14 are shown in Table R-69.

Future Devices and Costs

The future public water supply needs of aArea 14 can be met by providing river and/or lake intakes and pumping stations and additional water treatment plant capacity for all Study bench mark years, and additional reservoir storage for 2000 and 2020. Additional diversion from Area 15 (Delaware River) is anticipated for 2000 and 2020. For the year 2020, additional diversion, other than that from Area 15, will be required. Potential solutions to the 2020 supply problem would

FIGURE R-19

AREA 14 NORTHERN NEW JERSEY

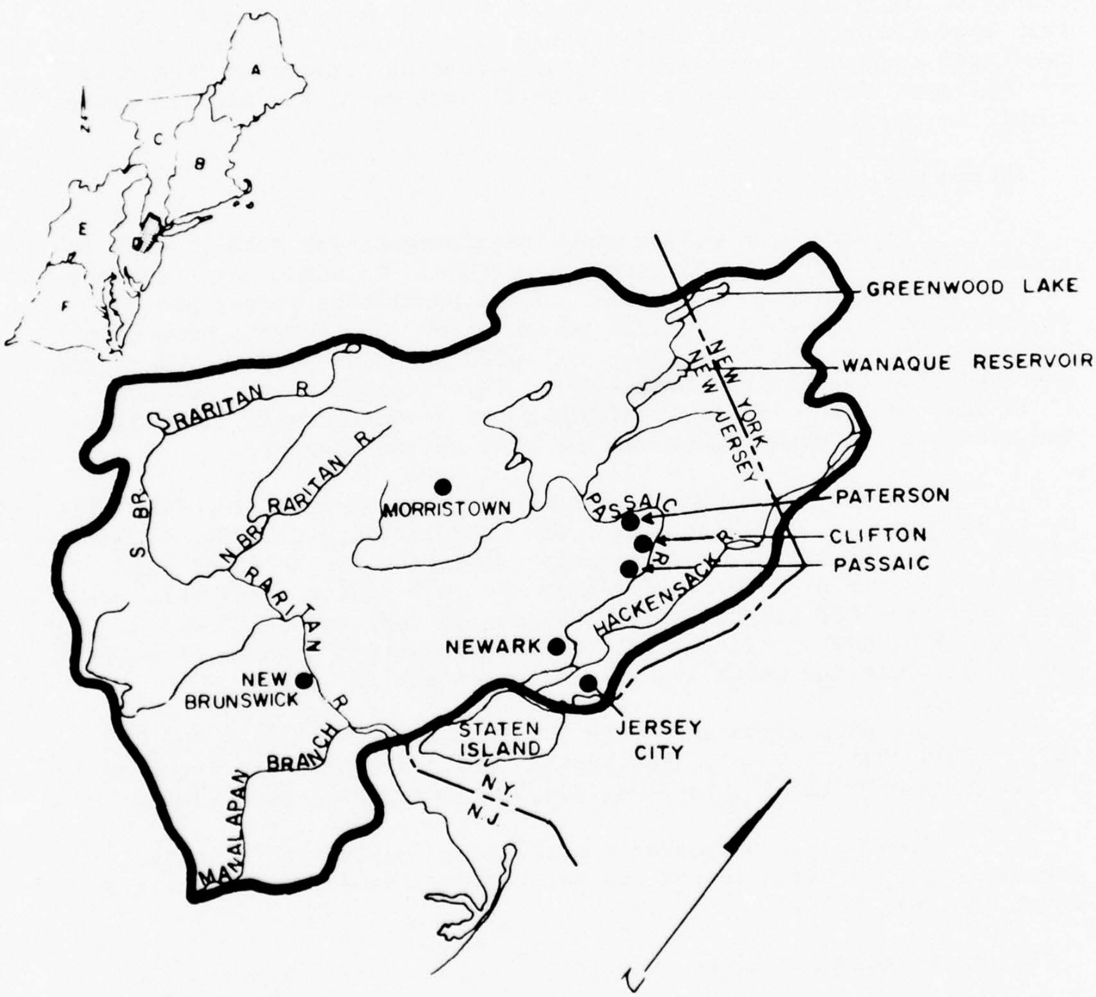


TABLE R-69
PUBLIC WATER SUPPLY - AREA 14

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	4,387	4,124	3,483	513
1980				
EQ	5,021	4,770	4,873	641
NE	5,192	4,935	5,121	670
RD	5,192	4,935	5,259	675
2000				
EQ	6,169	5,922	7,825	1,096 1/
NE	6,720	6,446	8,702	1,231 1/
RD	6,720	6,446	8,937	1,277 1/
2020				
EQ	7,181	6,965	12,513	1,678 1/
NE	8,428	8,208	14,591	2,016 1/
RD	8,428	8,208	14,984	2,133 1/

1/ Includes incremental increase of self-supplied industrial fresh water.

include diversion directly from Area 12 (Hudson River) into Area 14, or from Area 17 (Susquehanna River) into Area 15 to augment the diversion into Area 14. The devices and costs shown in Table R-70 are based, for the purposes of this Appendix, on diversion from the Delaware and Susquehanna Rivers in 2020. This involved the least economic cost for the quantities required to satisfy the public water supply needs. Reference is made to the demand and supply model analyses in Appendix T, Plan Formulation, in which all withdrawal purposes are considered in the development of the framework program.

Devices that could satisfy the increased public water supply requirements, including storage necessary to maintain diversion flows, and the estimated costs for these facilities are shown in Table R-70.

TABLE R-70
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 14
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	22	16.00	27	17.60	28	17.70
Intake & Pumping	22	.12	27	.15	28	.15
Diversion	-	-	-	-	-	-
Ground Water	26	1.48	31	1.77	32	1.83
2000						
Storage	33,400	21.30	75,000	122.00	75,000	122.00
Treatment Plant	234	63.50	363	86.50	370	87.50
Intake & Pumping	173	.93	193	1.04	200	1.08
Diversion	90	35.60	90	35.60	90	35.60
Ground Water	124	7.08	154	8.95	163	9.47
2020						
Storage	66,500	41.10	220,000	75.90	280,000	231.00
Treatment Plant	655	120.00	860	142.00	961	149.00
Intake & Pumping	580	3.13	792	4.28	886	4.78
Diversion	480	66.00	670	108.00	760	144.00
Ground Water	-	-	-	-	-	-

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 14 is 1,046 m.g.d., of which 278 m.g.d. are self-supplied, 60 m.g.d. are publicly-supplied and 708 m.g.d. are brackish. The chemical and paper industries are the major water users in the Area with respective self-supplied intakes of 110 m.g.d. and 75 m.g.d. Other significant self-supplied water-using industries include transportation equipment (14 m.g.d.), machine equipment (13 m.g.d.) primary metals (12 m.g.d.) and fabrics (10 m.g.d.). The brackish water intake is mainly for the chemical and petroleum industries.

Future Use

The increase in industrial water requirements is in part indicative of the Area's projected industrial growth. The 2020 total intake requirements are expected to be 3,175 m.g.d. (EQ), 3,573 m.g.d. (NE) and 3,966 m.g.d. (RD). As discussed in the section on the Area's public water, after 1980 any additional fresh water that would normally be self-supplied will be from public sources. Therefore, the self-supplied water requirements for 1980, 441 m.g.d. (EQ), 442 m.g.d. (NE) and 450 m.g.d. (RD), will remain constant through 2020. The total fresh water needs will increase during the Study period with 2000 requirements of 808 m.g.d. (EQ) 859 m.g.d. (NE) and 915 m.g.d. (RD), and 2020 requirements of 1,198 m.g.d. (EQ) and 1,336 m.g.d. (NE) and 1480 m.g.d. (RD). The transfer to the public supply for 2000 will be 209 m.g.d. (EQ), 248 m.g.d. (NE) and 286 m.g.d. (RD), and for 2020, 506 m.g.d. (EQ) 609 m.g.d. (NE) and 714 m.g.d. (RD).

The major fresh water-using industries in 2020 are shown in Table R-71.

TABLE R-71
2020 INDUSTRIAL TOTAL FRESH WATER REQUIREMENTS - AREA 14
(m.g.d.)

INDUSTRY	OBJECTIVE EQ	NE	RD
Paper	225	287	318
Chemicals	171	193	214
Primary Metals	149	167	186
Fabrics	117	132	146
Machine Equipment	108	121	135
Food	81	92	101
Electrical Equipment	71	81	90
Rubber	47	52	58
Metal Products	43	49	54
Transportation Equipment	42	48	52

The brackish water intake will be use mainly for the petroleum, chemicals, primary metals industries.

Area 14's present and projected industrial water requirements are shown in Table R-72.

TABLE R-72
INDUSTRIAL WATER SUPPLY - AREA 14
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	1,046	278	60	0	708	93
1980						
EQ	1,598	441	93	0	1,064	146
NE	1,599	442	93	0	1,064	146
RD	1,643	450	95	0	1,098	149
2000						
EQ	2,295	441 1/	367 1/	0	1,487	209
NE	2,418	442 1/	417 1/	0	1,559	218
RD	2,581	450 1/	465 1/	0	1,666	236
2020						
EQ	3,175	441 1/	757 1/	0	1,977	281
NE	3,573	442 1/	894 1/	0	2,237	315
RD	3,966	450 1/	1,030 1/	0	2,486	351

1/ Incremental increases of self-supplied fresh water were transferred to publicly-supplied fresh water.

Future Devices and Costs

Self-supplied industrial water supply in Area 14 is presently supplied from river and/or intakes, ground water and brackish water. Through 1980, it is expected that the future needs will be met in a similar manner. Before the year 2000, the projected need for ground water is expected to reach the availability of the resource in the Area. This means that after 1980, the fresh water portion of the self-supplied industrial needs will be supplied from surface sources. In

addition, it is anticipated that after 1980, surface water in the Area will be so limited as to preclude additional development for private use. As a consequence, the incremental increases in fresh surface water after the year 1980 can be expected to be supplied from public water supply systems.

Devices that could satisfy the incremental increases in self-supplied industrial water and their estimated costs are shown in Table R-73.

TABLE R-73
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 14
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	108	.58	109	.59	114	.62
Brackish Water						
Intake & Pumping	356	1.92	356	1.92	390	2.11
Ground Water	55	3.15	55	3.15	58	3.32
2000						
Fresh Water						
Intake & Pumping	-	-	-	-	-	-
Brackish Water						
Intake & Pumping	423	2.28	495	2.67	568	3.07
Ground Water	-	-	-	-	-	-
2020						
Fresh Water						
Intake & Pumping	-	-	-	-	-	-
Brackish Water						
Intake & Pumping	490	2.65	678	3.66	820	4.43
Ground Water	-	-	-	-	-	-

AREA 15. DELAWARE RIVER BASIN

PUBLIC WATER

Present Use

The total population of Area 15 is 6,719,000, of which 5,998,000, or approximately 89%, are served by 410 central water supply systems. These systems, which distribute an average of 800 m.g.d., utilize surface sources for about 75% of their supply with ground water development accounting for the balance. Diversion from Area 17 (Susquehanna River) provides a minor portion of the Area's surface water supply.

Future Use

Public water use is projected to increase for all objectives during the Study period. By 2020, the anticipated requirements will be 1,709 m.g.d. (EQ), 2,039 m.g.d. (NE) and 2,056 m.g.d. (RD). The population served and per capita income will also increase. The 2020 NE and RD population served will be 10,866,000, while for EQ it will be 9,291,000. Per capita income has been projected to 2020 figures of $10,912 (EQ), $12,723 (NE) and $13,067 (RD).

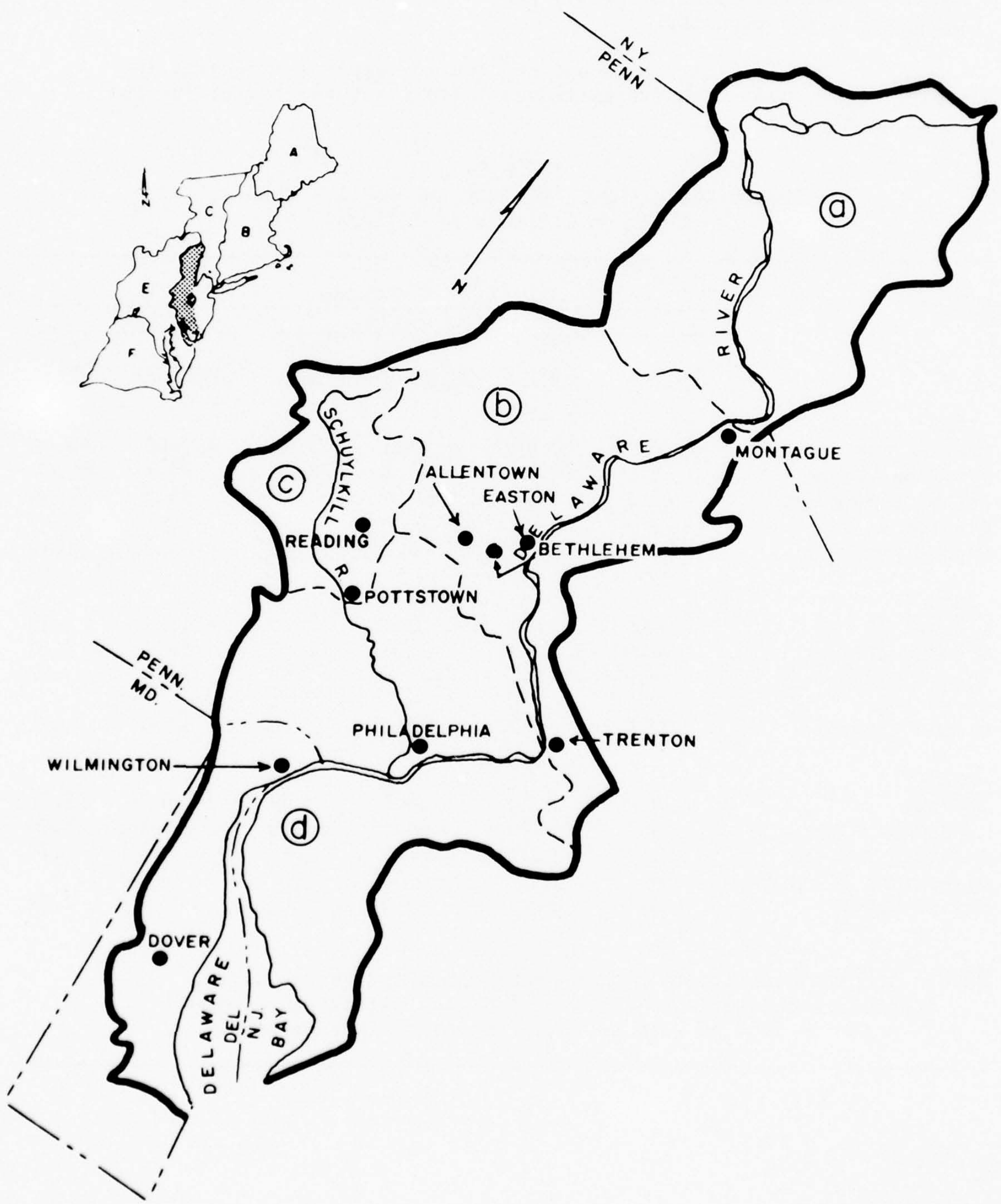
Present and projected public water use, population, population served and per capita income for Area 15 are shown in Table R-74.

TABLE R-74
PUBLIC WATER SUPPLY - AREA 15

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	6,719	5,998	2,940	800
1980				
EQ	7,546	6,641	4,116	963
NE	7,804	6,886	4,325	1,008
RD	7,804	6,886	4,442	1,015
2000				
EQ	8,822	7,851	6,628	1,277
NE	9,610	8,533	7,370	1,413
RD	9,610	8,533	7,569	1,425
2020				
EQ	10,099	9,291	10,912	1,709
NE	11,853	10,866	12,723	2,039
RD	11,853	10,866	13,067	2,056

FIGURE R-20

AREA 15 DELAWARE RIVER BASIN



Future Devices and Costs

Area 15's future public water needs can be met by providing additional reservoir capacity, intakes and pumping stations and wells for all timer frames of the Study period as well as additional water treatment plant capacity.

Devices that could satisfy the incremental increases in public water supply and the estimated costs for these facilities are shown in Table R-75.

TABLE R-75
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 15
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage (1)	34,000	37.90	43,000	47.90	45,000	50.30
Treatment Plant	68.3	62.90	87.0	78.00	90.8	80.50
Intake & Pumping	42.3	.23	54.0	.29	55.8	.30
Diversion	-	-	-	-	-	-
Ground Water	37.0	1.85	48.0	2.43	49.0	2.48
2000						
Storage	42,000	21.00	43,000	23.10	43,000	23.10
Treatment Plant	192.0	135.50	246.6	171.50	250.0	173.10
Intake & Pumping	85.0	.46	109.6	.59	111.0	.60
Diversion	-	-	-	-	-	-
Ground Water	72.0	3.72	93.0	4.86	94.0	4.91
2020						
Storage	9,900	11.50	14,400	16.80	14,500	16.80
Treatment Plant	283.0	164.70	246.6	230.30	413	231.90
Intake & Pumping	93.8	.51	109.6	.59	137.0	.74
Diversion	-	-	-	-	-	-
Ground Water	99.0	5.26	93.0	7.83	145.0	7.88

Note: Storage quantities in acre-feet; other devices in m.g.d.
(1) Assumes completion of Tocks Island and Beltzville project prior to 1980 in part for water needs outside area 15.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The industrial water requirements for Area 15 are the highest of all the Areas in the North Atlantic Region. The total intake is 1,652 m.g.d., of which 1,000 m.g.d. are self-supplied, 119 m.g.d. are publicly-supplied and 533 m.g.d. are brackish water. The largest self-supplied industrial water user in the Area is the primary metals industry with an intake of 475 m.g.d., followed by petroleum (190 m.g.d.), chemicals (124 m.g.d.), paper (77 m.g.d.) and food (30 m.g.d.). Other industries in the Area with self-supplied intakes over 10 m.g.d. are fabrics, glass and clay, machine equipment and transportation equipment. The bulk of the brackish water is used by the petroleum, primary metals and chemical industries.

Future Use

Area 15's projected industrial water requirements, both total and self-supplied, will continue to be the highest in the North Atlantic Region. In 2020, the self-supplied fresh water requirements are expected to be 6,024 m.g.d. (EQ), 6,788 m.g.d. (NE) and 7,526 m.g.d. (RD). Use of brackish water should be expected to increase faster than this as limitations on fresh water availability are likely to occur.

The projected largest self-supplied industrial water users in 2020 are shown in Table R-76.

TABLE R-76
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 15
(m.g.d.)

		OBJECTIVE	
INDUSTRY	EQ	NE	RD
Primary Metals	2,941	3,313	3,674
Petroleum	1,458	1,642	1,821
Paper	387	436	484
Chemicals	332	374	415
Food	185	208	231
Glass and Clay	185	183	231
Machine Equipment	162	90	203
Electrical Equipment	80	90	100
Fabrics	72	81	90
Rubber	66	74	82
Metal Products	48	55	60
Transportation Equipment	47	53	59

Brackish water will be used mostly by the petroleum, primary manufacturing and chemical industries.

Present industrial water use and projected industrial water requirements for Area 15 are shown in Table R-77.

TABLE R-77
INDUSTRIAL WATER SUPPLY - AREA 15
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	1,652	1,000	119	0	533	177
1980						
EQ	3,380	1,897	217	0	1,266	339
NE	3,381	1,897	217	0	1,267	340
RD	3,474	1,950	220	0	1,304	349
2000						
EQ	6,393	3,574	402	0	2,417	633
NE	6,750	3,769	425	0	2,556	667
RD	7,197	4,018	450	0	2,729	713
2020						
EQ	10,650	6,024	638	0	3,988	1,053
NE	11,995	6,788	717	0	4,490	1,188
RD	13,305	7,526	795	0	4,984	1,316

Future Devices and Costs

River and/or lake intakes, wells and brackish water furnish the water to meet the present self-supplied industrial water needs. It is anticipated that Area 15's future needs, through the year 2000, will be met in the same manner and approximately the same proportion. However, the projected ground water development for the year 2020 are expected to exceed the limit of practical development as given in Appendix D. It is assumed that that portion of the fresh water supply which cannot be furnished from ground water development will be obtained from surface sources.

Table R-78 indicates devices that could satisfy the incremental increases in self-supplied industrial water supply and the estimated costs for these facilities.

TABLE R-78
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 15
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	666	3.60	666	3.60	705	3.81
Brackish Water						
Intake & Pumping	733	3.96	734	3.96	771	4.16
Ground Water	231	12.60	231	12.60	245	13.40
2000						
Fresh Water						
Intake & Pumping	1,244	6.72	1,389	7.50	1,535	8.29
Brackish Water						
Intake & Pumping	1,151	6.22	1,289	6.96	1,425	7.70
Ground Water	433	29.10	483	32.50	533	35.90
2020						
Fresh Water						
Intake & Pumping	1,833	9.90	2,529	13.66	3,085	16.66
Brackish Water						
Intake & Pumping	1,571	8.48	1,934	10.44	2,255	12.18
Ground Water	617	41.50	490	33.00	423	28.50

AREA 16. COASTAL NEW JERSEY

PUBLIC WATER

Present Use

The total population of Area 16 is 760,000 of which 716,000 or about 94%, are served by 100 central water supply systems. These systems, which distribute an average of 86 m.g.d., utilize surface supplies for approximately 36% of their water, with the balance developed from ground water.

Future Use

The projected public water supply requirements will increase during the life of the Study for all objectives. The 2020 needs are expected to be 294 m.g.d. (EQ) 351 m.g.d. (NE) and 353 m.g.d. (RD). The population served and per capita income will also rise throughout the Study period with 2020 population served projected to be 2,234,000 for the NE and RD objectives and 1,912,000 for the EQ objective. Per capita income for 2020 is expected to be $11,792 (EQ) $13,750 (NE) and $14,121 (RD).

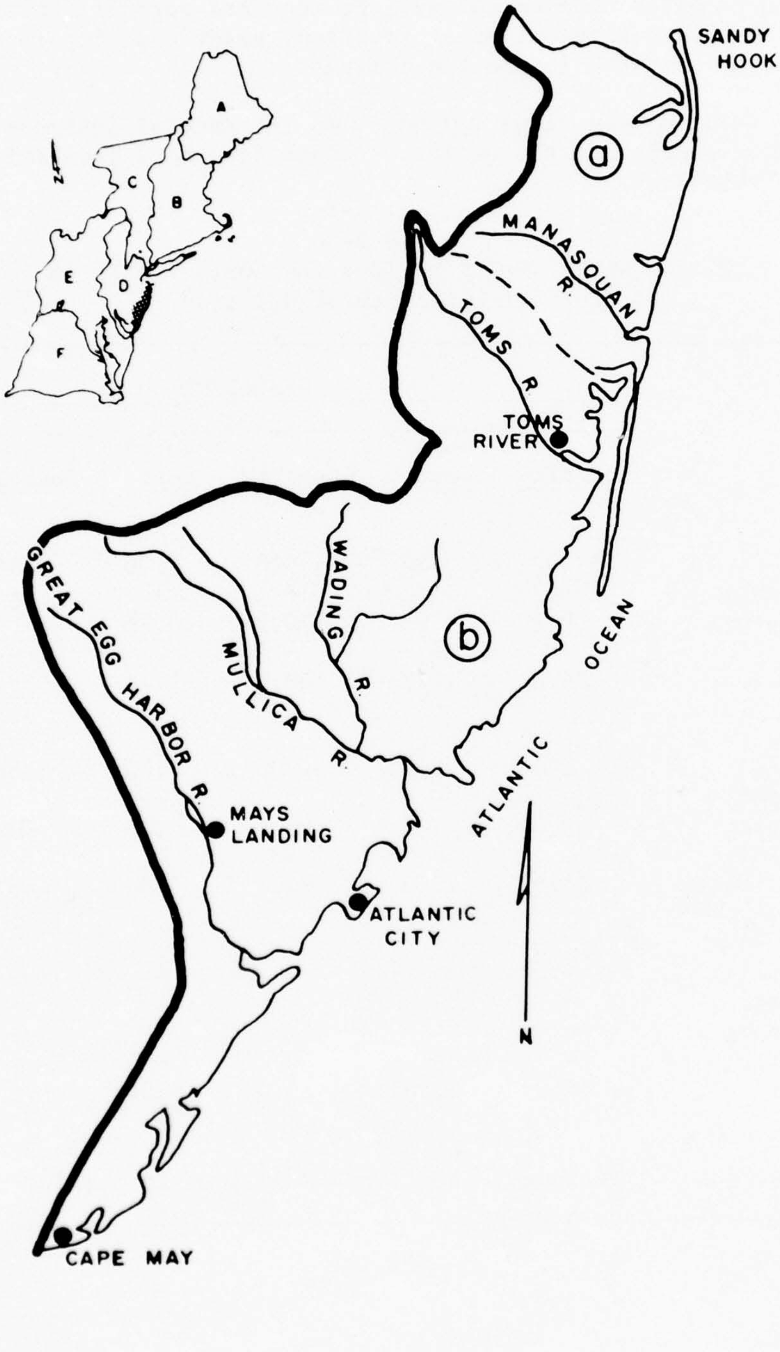
Area 16's present and projected public water supply requirements, population, population served and per capita income are shown in Table R-79.

TABLE R-79
PUBLIC WATER SUPPLY - AREA 16

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	760	716	3,018	86
1980				
EQ	1,046	994	4,527	127
NE	1,082	1,033	4,757	133
RD	1,082	1,033	4,885	134
2000				
EQ	1,567	1,520	7,337	210
NE	1,707	1,655	8,160	233
RD	1,707	1,655	8,380	235
2020				
EQ	1,951	1,912	11,792	294
NE	2,290	2,234	13,750	351
RD	2,290	2,234	14,121	353

FIGURE R-21

AREA 16 COASTAL NEW JERSEY



Future Devices and Costs

The future public water supply can be met by providing additional reservoir capacity and intakes and pumping stations for 1980 and 2000. Ground water development will be required for all Study time frames. There is sufficient water treatment plant capacity in the Area at present to meet the future requirements.

Devices that could satisfy the incremental increases in public water supply and the estimated costs for these facilities are shown in Table R-80.

TABLE R-80
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 16
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	3,500	3.80	4,000	4.30	4,100	4.50
Treatment Plant	-	-	-	-	-	-
Intake & Pumping	9.2	.05	10.5	.06	10.8	.06
Diversion	-	-	-	-	-	-
Ground Water	26.0	1.22	30.0	1.41	65.0	1.45
2000						
Storage	3,100	3.40	3,800	4.10	3,800	4.10
Treatment Plant	-	-	-	-	-	-
Intake & Pumping	9.2	.05	10.5	.06	10.8	.06
Diversion	-	-	-	-	-	-
Ground Water	53.0	2.53	64.0	3.06	65.0	3.11
2020						
Storage	-	-	-	-	-	-
Treatment Plant	-	-	-	-	-	-
Intake & Pumping	-	-	-	-	-	-
Diversion	-	-	-	-	-	-
Ground Water	54.0	2.58	75.0	3.64	75.0	3.64

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The industrial water requirements for Area 16 are low, with a total intake of only 28 m.g.d. Of this total, 3 m.g.d. are self-supplied and 25 m.g.d. are brackish. There is no publicly-supplied industrial water in the Area at present. The chemicals and transportation equipment industries are the fresh water users in the Area with respective withdrawals of 2 m.g.d. and 1 m.g.d. The bulk of the brackish water use is for the chemicals industry with a present use of 19 m.g.d.

Future Use

The future industrial water requirements are reflective of the projected growth of the Area, although the total needs are low when compared to other Areas in the NAR. The 2020 total intake requirements are expected to be 99 m.g.d. (EQ), 113 m.g.d. (NE) and 125 m.g.d. (RD). The self-supplied intake needs will be 16 m.g.d. (EQ), 20 m.g.d. (NE) and 21 m.g.d. (RD). Brackish water requirements will be 77 m.g.d. (EQ), 85 m.g.d. (NE) and 96 m.g.d. (RD).

Projected major industrial self-supplied fresh water users are listed in Table R-81.

TABLE R-81
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 16
(m.g.d.)

INDUSTRY	OBJECTIVE		
	EQ	NE	RD
Chemical	4	5	5
Electrical Equipment	3	4	4
Food	2	3	3
Metal Products	2	2	2
Transportation Equipment	2	2	2
Scientific Instruments	1	1	1

The bulk of the brackish water will be used by the chemicals, glass and clay, and food industries.

Table R-82 shows the present and projected industrial water requirements for Area 16.

Future Devices and Costs

River intakes, brackish water and ground water presently satisfy the need for self-supplied industrial water in Area 16. It is expected

TABLE R-82
INDUSTRIAL WATER SUPPLY - AREA 16
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	28	3	0	0	25	2
1980						
EQ	50	7	0	0	43	5
NE	50	7	0	0	43	5
RD	51	7	0	0	44	5
2000						
EQ	75	11	3	0	61	7
NE	82	13	3	0	66	7
RD	87	13	4	0	70	7
2020						
EQ	99	16	6	0	77	8
NE	113	20	8	0	85	10
RD	125	21	8	0	96	10

that the future needs will be met in the same manner and in approximately the same proportion as now exists.

Devices that could satisfy the incremental increases in self-supplied industrial water supply and the estimated costs of these facilities are show in Table R-83.

TABLE R-83
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 16
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water Intake & Pumping	3	.02	3	.02	3	.02
Brackish Water Intake & Pumping	18	.10	18	.10	19	.10
Ground Water	1	.05	1	.05	1	.09
2000						
Fresh Water Intake & Pumping	3	.02	4	.02	4	.02
Brackish Water Intake & Pumping	18	.10	23	.12	26	.14
Ground Water	1	.05	2	.09	2	.09
2020						
Fresh Water Intake & Pumping	5	.03	5	.03	5	.03
Brackish Water Intake & Pumping	16	.09	19	.10	26	.14
Ground Water	2	.09	2	.09	3	.14

AREA 17. SUSQUEHANNA RIVER BASIN

PUBLIC WATER

Present Use

The total population of Area 17 is 3,362,000, of which about 78%, or 2,627,000 people, are supplied from the over 400 central water supply systems in the Area. These systems distribute an average of 340 m.g.d. Approximately 51% of the water for public supply is obtained from surface sources with the balance developed from ground water.

Future Use

Projected public water use will increase throughout the Study period with anticipated 2020 requirements of 899 m.g.d. for EQ, 1,053 m.g.d. for NE, and 1,104 m.g.d. for RD. The factors affecting public water supply; population served and per capita income, also will increase during the Study. For example, by 2020, the NE and RD populations served are expected to be 5,417,000 and the EQ figure will be 4,624,000. Per capita income for 2020 is anticipated to rise to $10,027 under EQ, $11,692 under NE and $13,007 under RD.

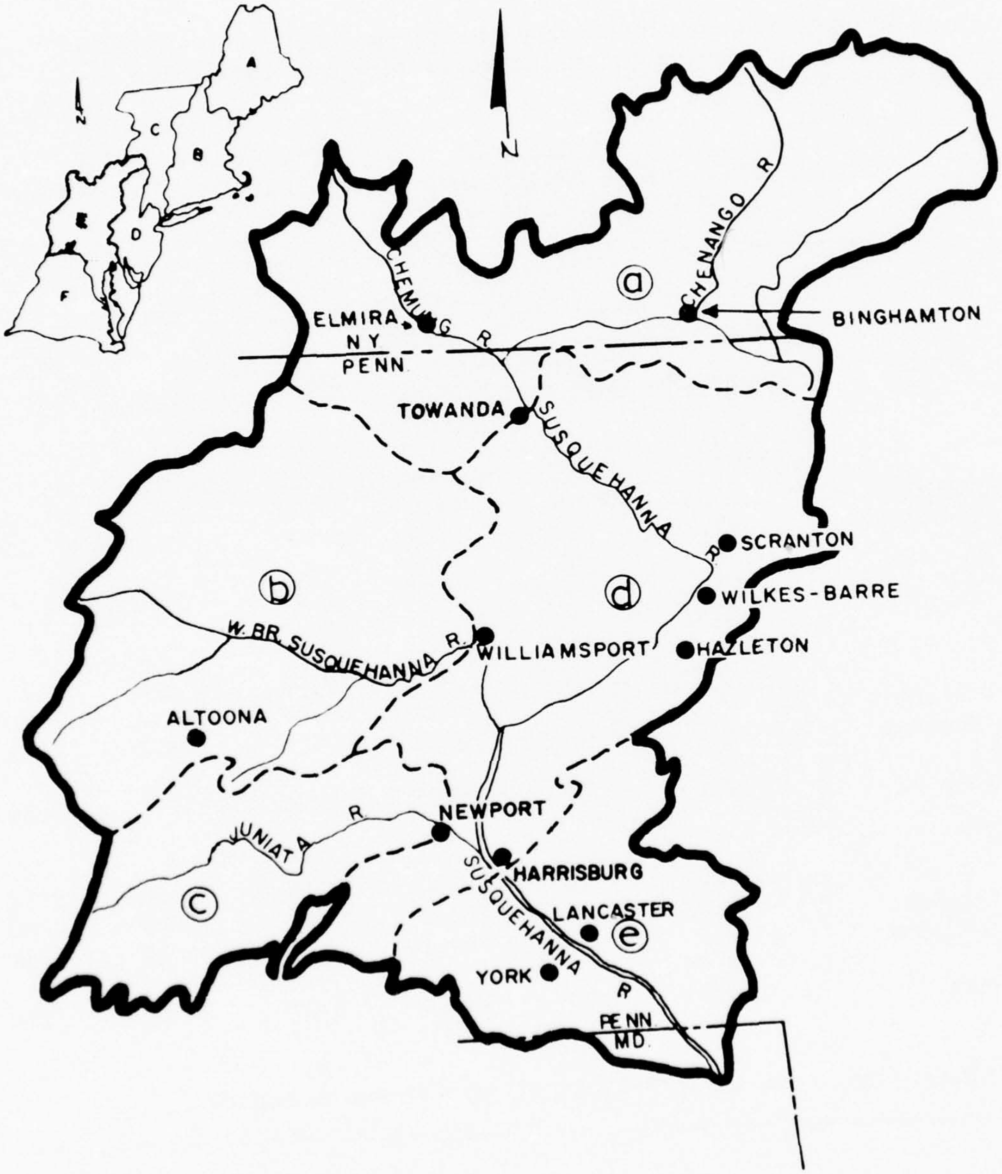
Present and projected public water supply requirements, population, population served and per capita income for Area 17 are shown in Table R-84.

TABLE R-84
PUBLIC WATER SUPPLY - AREA 17

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	3,362	2,627	2,397	340
1980				
EQ	3,774	3,057	3,465	428
NE	3,903	3,153	3,641	445
RD	3,903	3,153	3,739	449
2000				
EQ	4,500	3,825	5,847	625
NE	4,902	4,151	6,502	681
RD	4,902	4,151	6,677	693
2020				
EQ	5,195	4,624	10,027	899
NE	6,097	5,417	11,692	1,053
RD	6,097	5,417	13,007	1,104

FIGURE R-22

AREA 17 SUSQUEHANNA RIVER BASIN



Future Devices and Costs

The future public water supply needs of Area 17 can be met by providing additional reservoir capacity, intakes and pumping stations and wells for all time frames of the Study period. Additional water treatment plant capacity will also be required for all time frames.

Devices that could satisfy the incremental increases in public water supply and the estimated costs of these facilities are shown in Table R-85.

TABLE R-85
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 17
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	139,000	37.40	166,000	41.50	172,000	43.00
Treatment Plant	36.3	26.80	44.0	30.60	45.6	31.50
Intake & Pumping	13.3	.07	16.0	.09	16.6	.09
Diversion	-	-	-	-	-	-
Ground Water	43.0	1.58	52.0	1.91	54.0	1.99
2000						
Storage	61,000	17.20	73,000	20.70	75,000	21.20
Treatment Plant	87.9	57.70	105.0	69.20	108.2	71.50
Intake & Pumping	30.9	.17	37.0	.20	38.2	.21
Diversion	-	-	-	-	-	-
Ground Water	97.0	3.57	117.0	4.31	121.0	4.56
2020						
Storage	3,800	2.40	5,200	3.10	5,700	3.50
Treatment Plant	119.9	79.30	163.2	100.90	180	110.60
Intake & Pumping	39.9	.22	54.2	.29	60	.32
Diversion	-	-	-	-	-	-
Ground Water	135.0	4.98	184.0	6.83	203.0	7.67

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake for Area 17 is 380 m.g.d., of which 323 m.g.d. are self-supplied and 57 m.g.d. are from public sources. There is no brackish water used by industry in the Area. The industries using significant amounts of self-supplied water are paper (94 m.g.d.), chemicals (71 m.g.d.), food (45 m.g.d.), primary metals (38 m.g.d.), machine equipment (36 m.g.d.), glass and clay (11 m.g.d.) and transportation equipment (10 m.g.d.).

Future Use

Area 17's predicted large growth is reflected in the projected increases in industrial water intake throughout the Study period. By the year 2020, the total industrial water intake is expected to be 2,102 m.g.d. (EQ), 2,366 m.g.d. (NE) and 2,623 m.g.d. (RD), of which 1,721 m.g.d., 1,938 m.g.d. and 2,150 m.g.d., respectively, will be self-supplied, with the balance coming from public supply.

The largest self-supplied, fresh water-using industries in Area 17 are shown in Table R-86. It is anticipated that there will be no future demand for brackish water.

TABLE R-86
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 17
(m.g.d.)

INDUSTRY	OBJECTIVE		
	EQ	NE	RD
Paper	408	459	509
Machine Equipment	357	402	446
Food	278	313	347
Chemicals	170	192	213
Primary Metals	158	178	198
Glass and Clay	105	119	132
Electrical Equipment	64	72	80

Area 17's present and projected industrial water requirements are shown in Table R-87.

Future Devices and Costs

River and/or lake intakes and wells furnish the water required to satisfy the present self-supplied industrial water needs in the Area. It is expected that the future needs will be met in the same manner and

TABLE R-87
INDUSTRIAL WATER SUPPLY - AREA 17
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	380	323	57	0	0	51
1980						
EQ	700	590	110	0	0	96
NE	700	590	110	0	0	96
RD	717	603	114	0	0	99
2000						
EQ	1,270	1,054	216	0	0	173
NE	1,338	1,113	225	0	0	182
RD	1,428	1,189	239	0	0	195
2020						
EQ	2,102	1,721	381	0	0	297
NE	2,366	1,938	428	0	0	334
RD	2,623	2,150	473	0	0	367

in approximately the same proportion that now exists.

Table R-88 shows devices that could satisfy the incremental increases in industrial self-supplied water supply and the estimated costs of these facilities.

TABLE R-88
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 17
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water Intake & Pumping	220	1.19	220	1.19	231	1.25
Brackish Water Intake & Pumping	-	-	-	-	-	-
Ground Water	47	1.73	47	1.73	49	1.80
2000						
Fresh Water Intake & Pumping	382	2.06	430	2.32	483	2.61
Brackish Water Intake & Pumping	-	-	-	-	-	-
Ground Water	82	3.02	92	3.38	103	3.50
2020						
Fresh Water Intake & Pumping	549	2.96	679	3.67	791	4.27
Brackish Water Intake & Pumping	-	-	-	-	-	-
Ground Water	118	4.27	146	5.50	170	6.40

AREA 18. CHESAPEAKE BAY AND DELMARVA PENINSULA DRAINAGE

PUBLIC WATER

Present Use

The total population of Area 18 is 2,330,000 of which 1,791,000, or roughly 77%, obtain their water from the 140 central water systems in the Area. These systems distribute an average of 260 m.g.d. of water. Approximately 85% of the water for public supply is obtained from surface sources with the remainder developed from ground water. A portion of the Area's surface supply is a diversion of water entering Chesapeak Bay from the Lower Susquehanna River (Area 17). This supply is obtained just above Conowingo Dam, about 10 miles above the mouth of the river, and returned after use (less losses) to the upper Bay near Baltimore.

Future Use

Public water supply has been projected to increase during the Study period in line with the anticipated increases in population served and per capita income. The 2020 public supply requirements are expected to be 602 m.g.d. (EQ), 712 m.g.d. (NE) and 725 m.g.d. (RD). Population served by 2020 should be 2,904,000 (EQ) and 3,392,000 (NE & RD). Per capita income has been projected to grow to $11,072 (EQ), $12,910 (NE) and $13,258 (RD) by 2020.

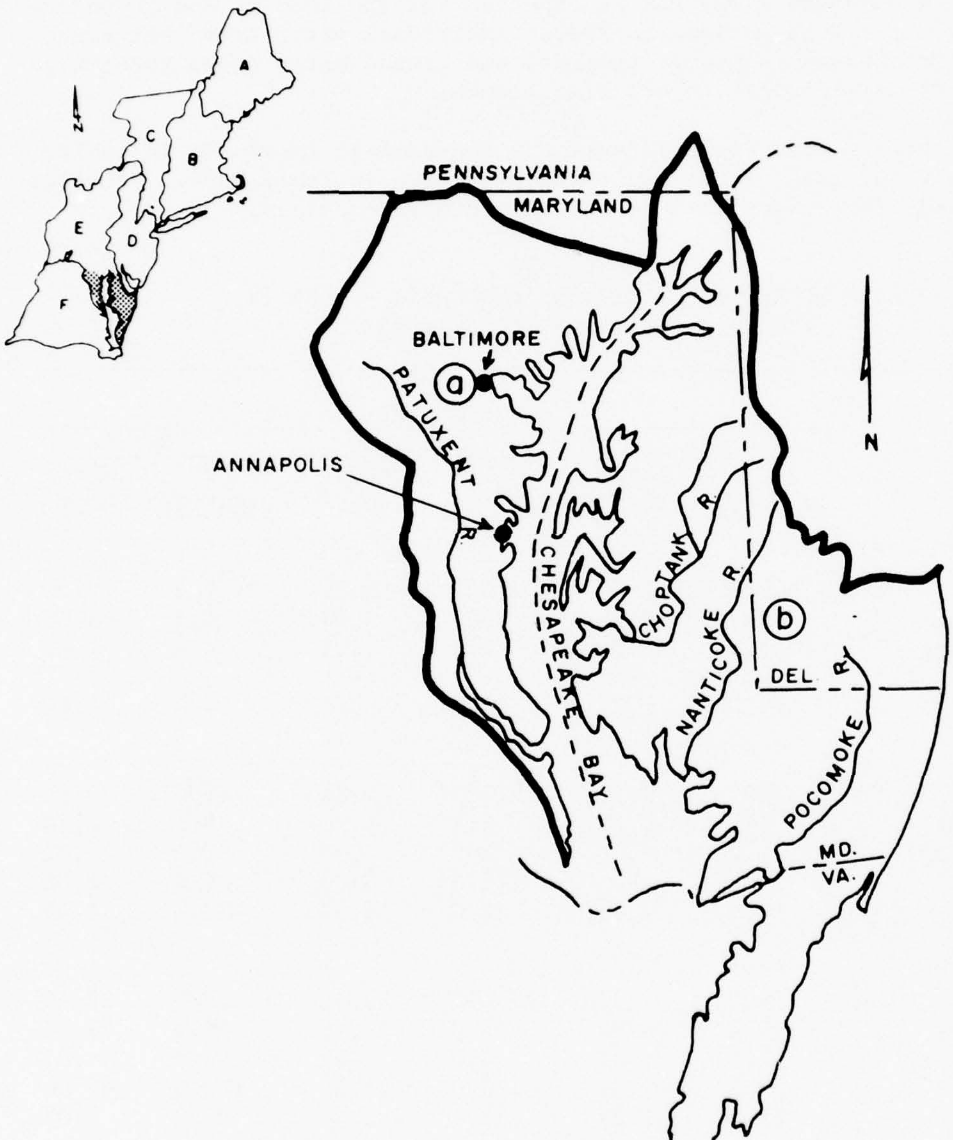
The present and projected public water supply requirements, total population, population served and per capita income for Area 18 are shown in Table R-89.

TABLE R-89
PUBLIC WATER SUPPLY - AREA 18

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	2,330	1,791	2,817	260
1980				
EQ	2,676	2,087	4,218	339
NE	2,767	2,149	4,432	352
RD	2,767	2,149	4,552	354
2000				
EQ	3,163	2,435	6,814	450
NE	3,445	2,667	7,577	498
RD	3,445	2,667	7,782	505
2020				
EQ	3,631	2,904	11,072	602
NE	4,261	3,392	12,910	712
RD	4,261	3,392	13,258	725

FIGURE R-23

AREA 18 CHESAPEAKE BAY AND DELMARVA PENINSULA DRAINAGE



Future Devices and Costs

The future public water supply needs of Area 18 can be met by providing additional reservoir capacity for all objectives for all Study time frames, except for the 2020 EQ objective. Additional transfer from the lower Susquehanna River can be expected for the 2000 NE and RD objectives, and for all objectives in 2020. Additional water treatment plant capacity, intakes and pumping stations, and ground water development will be needed for all objectives and time frames.

Devices that could satisfy the incremental increases in public water supply and their estimated costs are shown in Table R-90. Storages shown include those necessary to maintain diversion flows.

TABLE R-90
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 18
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	4,000	2.10	4,600	2.50	4,700	2.50
Treatment Plant	2.9	3.50	3.3	4.00	3.5	4.00
Intake & Pumping	1.6	.01	1.8	.01	1.9	.01
Diversion	-	-	-	-	-	-
Ground Water	12.0	.72	14.0	.84	14.0	.84
2000						
Storage	5,500	2.10	7,300	2.80	7,500	2.90
Treatment Plant	6.3	5.30	8.3	6.70	8.6	6.70
Intake & Pumping	2.0	.01	2.7	.02	2.8	.02
Diversion	-	-	125.0	3.00	125.0	3.00
Ground Water	17.0	1.03	22.0	1.32	23.0	1.39
2020						
Storage	-	-	123,000	23.40	123,000	23.40
Treatment Plant	40.8	13.90	57.0	17.10	59.1	17.60
Intake & Pumping	2.8	.02	4.0	.02	4.1	.02
Diversion	125.0	3.00	120.0	45.00	120.0	45.00
Ground Water	23.0	1.39	33.0	2.02	34.0	2.07

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake for Area 18 is 1,173 m.g.d., of which 154 m.g.d. are self-supplied, 45 m.g.d. are publicly-supplied, 120 m.g.d. are waste water, and 854 m.g.d. are brackish water. This is the only Area in the Region where waste water is utilized for industrial water supply. Sewage treatment plant effluent is used by the primary metals industry. The significant self-supplied water using industries in the Area are chemicals (50 m.g.d.) primary metals (47 m.g.d.) and food (18 m.g.d.) These same industries are the major users of brackish water.

Future Use

The industrial water use in Area 18 has been projected to increase in relation to the anticipated growth of the Area. The total water intake is expected to be 7,318 m.g.d. (EQ), 8,246 m.g.d. (NE) and 9,143 m.g.d. (RD) by the year 2020. Of these totals, the self-supplied fresh water will be 860 m.g.d., 968 m.g.d. and 1076 m.g.d., respectively. Waste water needs are projected to be 1138 m.g.d. (EQ), 1282 m.g.d. (NE) and 1422 m.g.d. (RD). If the available waste water is insufficient to meet the needs, the difference between the needs and availability can be supplied from brackish water. The waste water requirements are only for the primary manufacturing industry.

The largest self-supplied fresh water using industries for the year 2020 are shown in Table R-91.

TABLE R-91
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 18
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Primary Metals	360	405	449
Chemicals	132	149	165
Food	120	135	150
Electrical Equipment	44	50	55
Paper	29	33	36
Metal Products	27	30	34
Transportation Equipment	26	29	33
Glass and Clay	24	27	30

The bulk of the brackish water will be for primary metals.

Area 18's present and projected industrial water-use is shown in Table R-92.

TABLE R-92
INDUSTRIAL WATER SUPPLY - AREA 18
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	1,173	154	45	120	854	66
1980						
EQ	2,308	292	86	254	1,676	131
NE	2,308	292	86	254	1,676	131
RD	2,369	300	88	260	1,721	135
2000						
EQ	4,390	537	158	555	3,140	247
NE	4,633	568	167	585	3,313	265
RD	4,942	604	180	624	3,534	284
2020						
EQ	7,318	860	270	1,138	5,050	412
NE	8,246	968	309	1,282	5,687	467
RD	9,143	1,076	339	1,422	6,306	518

Future Devices and Costs

River intakes, ground water, brackish water and waste water presently satisfy the self-supplied industrial needs in Area 18. It is anticipated that future self-supplied industrial needs will continue to be met in a similar manner. However, there is a strong possibility that, after 2000, surface water sources for industrial use may require regulation which will either limit withdrawals or require cost-sharing by industry for the facilities needed to maintain minimum flows in the Area's rivers. While it can be assumed that cost-sharing may be necessary in the future, determination of these costs is beyond the scope of the NAR Study.

Devices that could satisfy the incremental increases in self-supplied industrial water supply and their estimated costs are shown in Table R-93.

TABLE R-93
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 18
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	117	.63	117	.63	124	.67
Brackish Water						
Intake & Pumping	822	4.44	822	4.44	867	4.68
Ground Water	21	1.25	21	1.25	22	1.32
Waste Water	134	.72	134	.72	140	.76
2000						
Fresh Water						
Intake & Pumping	208	1.12	235	1.27	259	1.40
Brackish Water						
Intake & Pumping	1,464	7.91	1,637	8.84	1,813	9.79
Ground Water	37	2.17	41	2.48	45	2.72
Waste Water	301	1.63	331	1.79	364	1.95
2020						
Fresh Water						
Intake & Pumping	275	1.49	340	1.84	402	2.17
Brackish Water						
Intake & Pumping	1,910	10.31	2,374	12.82	2,772	14.97
Ground Water	48	2.90	60	3.63	70	4.24
Waste Water	583	3.15	697	6.67	798	4.31

AREA 19. POTOMAC RIVER BASIN

PUBLIC WATER

Present Use

The 250 central water supply systems in Area 19 distribute an average of 360 m.g.d. to the 2,536,000 people they serve. This represents some 78% of Area 19's total population of 3,236,000. Surface water sources furnish approximately 93% of the public water supply, with the remainder developed from ground water. A small portion of the Area's surface supply is by diversion from Area 18 (Chesapeake Bay and Delmarva Peninsula Drainage). While the diverted water represents a net loss to users and instream uses in the Patuxent River and estuary, the diverted water (minus consumptive and evaporative losses) ultimately reaches Chesapeake Bay via the Potomac River in Area 19 a few miles south of where it would have originally and naturally entered the Bay.

Future Use

The Area's public water supply requirements are expected to increase throughout the life of the Study along with the population served and the per capita incomes. The 2020 public water needs will be 1211 m.g.d. (EQ), 1443 m.g.d. (NE) and 1493 m.g.d. (RD). Population served for 2020 is projected to be 7,517,000 (NE & RD) and 6,394,000 (EQ). Per capita income is expected to increase to $11,772 (EQ), $13,727 (NE) and $15,100 (RD) by the year 2020.

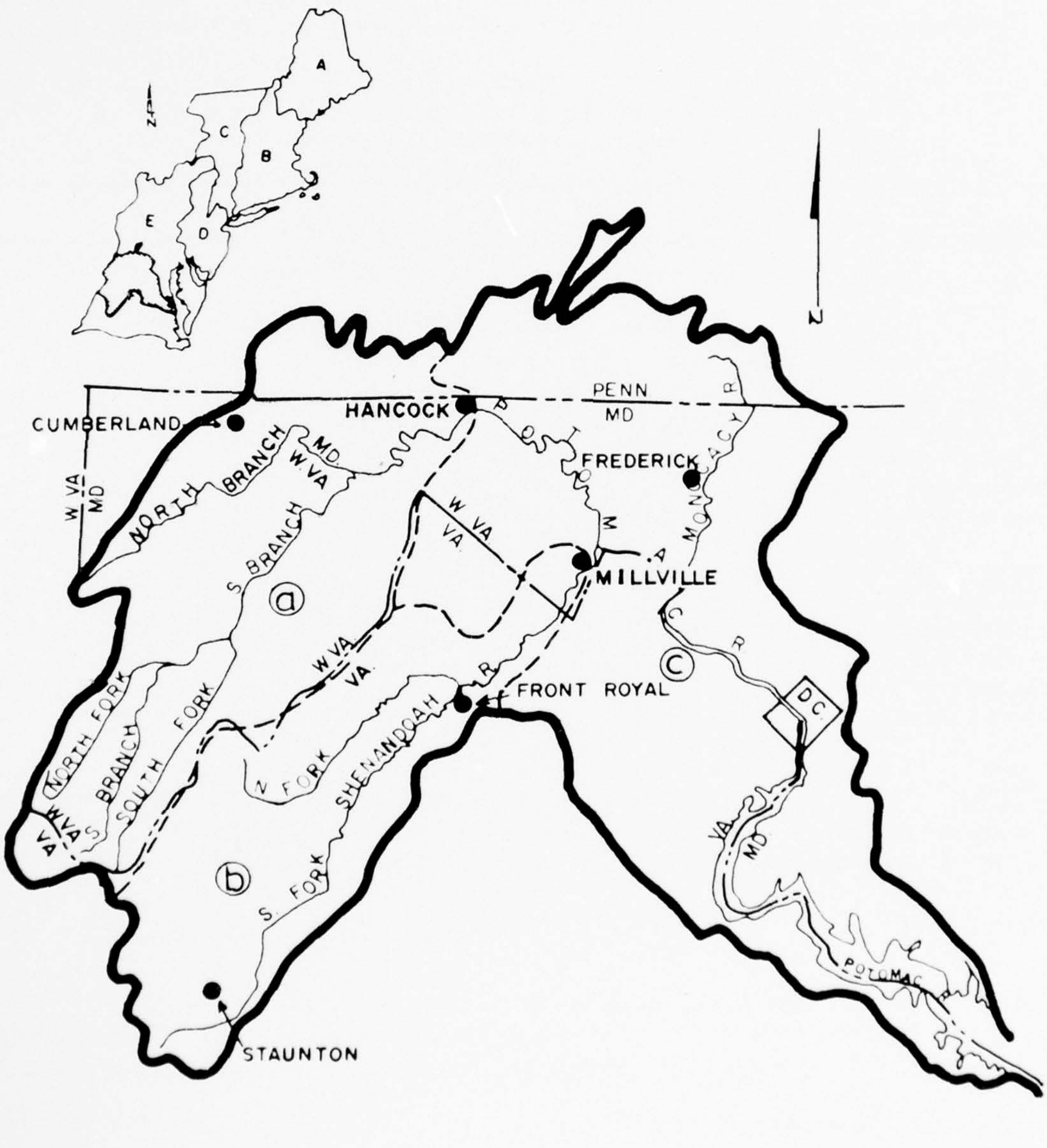
Table R-94 shows the Area's present and projected water supply requirements, total population, population served and per capita incomes.

TABLE R-94
PUBLIC WATER SUPPLY - AREA 19

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	3,236	2,536	3,041	360
1980				
EQ	4,288	3,387	4,566	522
NE	4,434	3,488	4,798	543
RD	4,434	3,488	4,928	547
2000				
EQ	5,818	4,829	7,251	816
NE	6,338	5,210	8,064	895
RD	6,338	5,210	8,604	916
2020				
EQ	7,350	6,394	11,772	1,211
NE	8,627	7,517	13,727	1,443
RD	8,627	7,517	15,100	1,493

FIGURE R-24

AREA 19 POTOMAC RIVER BASIN



Future Devices and Costs

The future public water supply requirements of Area 19 can be met by providing additional reservoir capacity, intakes and pumping stations and wells for all time frames of the Study period. Additional water treatment plant capacity will also be needed at each benchmark year.

Devices that could satisfy the incremental increases in public water supply and their estimated costs are shown in Table R-95.

TABLE R-95
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 19
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage (1)	16,500	16.20	18,600	18.40	19,000	18.80
Treatment Plant	109.4	87.60	123.5	97.00	126.0	101.70
Intake & Pumping	62.4	.34	70.5	.38	72.0	.39
Diversion	-	-	-	-	-	-
Ground Water	13.0	.50	15.0	.59	15.0	.59
2000						
Storage	200,000	95.80	240,000	115.10	250,000	119.80
Treatment Plant	293.3	187.20	351.6	211.70	368.7	232.50
Intake & Pumping	123.3	.67	147.6	.80	154.7	.84
Diversion	-	-	-	-	-	-
Ground Water	24.0	1.00	28.0	1.18	30.0	1.25
2020						
Storage	254,000	88.40	352,000	122.60	370,000	128.80
Treatment Plant	407.7	225.10	566.6	304.70	597	321.90
Intake & Pumping	141.7	.77	196.6	1.06	207	1.12
Diversion	-	-	-	-	-	-
Ground Water	32.0	1.34	44.0	1.99	46.0	2.08

Note: Storage quantities in acre-feet; other devices in m.g.d.
(1) Assumes completion of Bloomington project prior to 1980 insuring minimum flow below Washington and instream uses.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 19 is 299 m.g.d.,

of which 261 m.g.d. are self-supplied, 24 m.g.d. are publicly-supplied and 14 m.g.d. brackish. The largest self-supplied fresh water users in the Area are chemicals (155 m.g.d.), paper (57 m.g.d.), glass and clay (17 m.g.d.), and food (13 m.g.d.). The remaining self-supplied water is used by eight other industries, none of which has an intake greater than 5 m.g.d. The bulk of the brackish water use is for the chemical industry.

Future Use

The projected industrial growth for the Area is reflected in the anticipated greater needs for industrial water which will be 1,442 m.g.d. (EQ), 1,624 m.g.d. (NE) and 1,802 m.g.d. (RD) by the year 2020. Self-supplied fresh water needs for 2020 are expected to be 1,191 m.g.d. (EQ), 1,341 m.g.d. (NE) and 1,488 m.g.d. (RD).

The projected principal self-supplied water-using industries are shown in Table R-96. Brackish water will be used by the chemicals, glass and clay, and food industries.

TABLE R-96
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 19
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Chemicals	331	373	413
Paper	329	371	411
Glass and Clay	211	237	263
Food	117	132	147
Rubber	50	56	62
Machine Equipment	37	41	46
Electrical Equipment	31	35	39
Metal Products	19	21	24
Transportation Equipment	18	21	23

Present and projected industrial water use for Area 19 is shown in Table R-97.

Future Devices and Costs

The industries in Area 19 presently obtain self-supplied water from river and/or lake intakes, wells and brackish sources. It is expected that the future water supply needs will be satisfied in a similar manner.

TABLE R-97
INDUSTRIAL WATER SUPPLY - AREA 19
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	299	261	24	0	14	14
1980						
EQ	573	495	53	0	25	30
NE	573	495	53	0	25	30
RD	590	510	54	0	26	31
2000						
EQ	969	828	101	0	40	66
NE	1,020	868	109	0	43	68
RD	1,090	930	117	0	43	73
2020						
EQ	1,442	1,191	192	0	59	121
NE	1,624	1,341	216	0	67	136
RD	1,802	1,488	239	0	75	149

Table R-98 shows devices that could satisfy the incremental increases in self-supplied industrial water and the estimated costs of these facilities.

TABLE R-98
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 19
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	219	1.18	219	1.18	233	1.26
Brackish Water						
Intake & Pumping	11	.06	11	.06	12	.06
Ground Water	15	.59	15	.59	16	.63
2000						
Fresh Water						
Intake & Pumping	311	1.68	349	1.88	393	2.12
Brackish Water						
Intake & Pumping	15	.08	18	.10	17	.09
Ground Water	22	.91	24	1.00	27	1.20
2020						
Fresh Water						
Intake & Pumping	339	1.83	442	2.39	522	2.82
Brackish Water						
Intake & Pumping	19	.10	24	.13	32	.17
Ground Water	24	1.00	31	1.30	36	1.51

AREA 20. RAPPAHANNOCK AND YORK RIVER BASINS

PUBLIC WATER

Present Use

The total population of Area 20 is 316,000. Some 146,000 people, or approximately 46% of the total, are served by 57 central water supply systems. These systems, which distribute an average of 18 m.g.d., obtain about 83% of their water from surface sources, with the balance developed from ground water.

Future Use

Public water needs in Area 20 have been projected to increase throughout the Study period, together with population served and per capita income. The 2020 public water requirements will be 57 m.g.d. (EQ), 68 m.g.d. (NE) and 69 m.g.d. (RD). Population served in 2020 is expected to increase to 333,000 (EQ) and 390,000 (NE & RD) while per capita income will grow to $10,641 (EQ), $12,408 (NE), and $12,743 (RD).

Present and projected water supply requirements, total population, population served and per capita incomes for Area 20 are shown in Table R-99.

TABLE R-99
PUBLIC WATER SUPPLY - AREA 20

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	316	146	2,298	18
1980				
EQ	369	181	3,853	26
NE	382	186	4,049	26
RD	382	186	4,158	27
2000				
EQ	476	243	6,382	38
NE	518	264	7,097	42
RD	518	264	7,288	43
2020				
EQ	628	333	10,641	57
NE	737	390	12,408	68
RD	737	390	12,743	69

FIGURE R-25

AREA 20 RAPPAHANNOCK AND YORK RIVER BASINS

Future Devices and Costs

The future public water supply needs in Area 20 can be met by providing additional reservoir storage capacity in 1980 and 2020, while additional ground water development and water treatment plant capacity will be required for all time frames of the Study period.

Devices that could satisfy the incremental increases in public water supply and their estimated costs are shown in Table R-100.

TABLE R-100
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 20
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	71,000	25.40	71,000	25.40	80,000	28.60
Treatment Plant	4.9	2.20	4.9	2.20	5.5	2.20
Intake & Pumping	-	-	-	-	-	-
Diversion	-	-	-	-	-	-
Ground Water	1.3	.06	1.3	.06	1.5	.07
2000						
Storage	-	-	-	-	-	-
Treatment Plant	10.3	4.30	13.7	5.10	13.7	5.10
Intake & Pumping	-	-	-	-	-	-
Diversion	-	-	-	-	-	-
Ground Water	2.0	.09	2.7	.13	2.7	.13
2020						
Storage	3,100	2.10	4,100	2.40	4,100	2.40
Treatment Plant	13.0	5.30	17.7	6.20	17.7	6.20
Intake & Pumping	-	-	-	-	-	-
Diversion	-	-	-	-	-	-
Ground Water	3.2	.15	4.3	.20	4.3	.20

Note: Storage quantities in acre-feet; other devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

Area 20's total industrial water intake of 92 m.g.d. includes

50 m.g.d. of self-supplied fresh, 2 m.g.d. of publicly-supplied fresh, and 40 m.g.d. of brackish. The chemical industry is the only one in the Area which uses a significant amount of self-supplied water, some 48 m.g.d. Brackish water use is almost equally divided between the petroleum and paper industries with respective intakes of 19 m.g.d. and 17 m.g.d.

Future Use

The projected industrial water use is relatively small when compared with some of the other Areas in the NAR, but the increase expected throughout the Study period is indicative of the anticipated growth of the Area. The total industrial water intakes in 2020 are expected to be 484 m.g.d. (EQ), 545 m.g.d. (NE) and 603 m.g.d. (RD), of which 113 m.g.d., 129 m.g.d., and 143 m.g.d., respectively, are self-supplied.

The chemical industry will continue to be the major user of self-supplied water with intakes of 81 m.g.d. (EQ), 91 m.g.d. (NE) and 101 m.g.d. (RD). The balance of the self-supplied intake is distributed among 12 industries, none of which will use more than 7 m.g.d. The petroleum and paper industries will continue to be the major users of brackish water.

Present and projected industrial water requirements for Area 20 are shown in Table R-101.

TABLE R-101
INDUSTRIAL WATER SUPPLY - AREA 20
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	92	50	2	0	40	5
1980						
EQ	180	82	3	0	95	8
NE	180	82	3	0	95	8
RD	184	85	3	0	96	8
2000						
EQ	311	107	6	0	198	15
NE	329	115	6	0	208	15
RD	349	122	7	0	220	16
2020						
EQ	484	113	8	0	363	21
NE	545	129	8	0	408	25
RD	603	143	9	0	451	27

Future Devices and Costs

Self-supplied industrial water in Area 20 is presently obtained from river and/or lake intakes, brackish sources and wells, and it is anticipated that the future needs will be met in a similar fashion.

Table R-102 indicates devices that could satisfy the incremental increases in self-supplied industrial water supply and their estimated costs.

TABLE R-102
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 20
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	30	.16	30	.16	33	.18
Brackish Water						
Intake & Pumping	55	.30	55	.30	56	.30
Ground Water	2	.09	2	.09	2	.09
2000						
Fresh Water						
Intake & Pumping	23	.12	31	.17	35	.19
Brackish Water						
Intake & Pumping	103	.56	113	.61	124	.67
Ground Water	2	.09	2	.09	2	.09
2020						
Fresh Water						
Intake & Pumping	6	.03	13	.07	20	.11
Brackish Water						
Intake & Pumping	165	.89	200	1.08	231	1.25
Ground Water	-	-	1	.05	1	.05

AREA 21. JAMES RIVER BASIN

PUBLIC WATER

Present Use

The total population of Area 21 is 1,698,000, of which about 1,343,000 people, or 79% are supplied with water from 103 central water supply systems in the Area. Approximately 185 m.g.d. are distributed by the Area's central systems, of which about 94% is obtained from surface sources, with the balance developed from ground water. A small portion of the Area's surface supply is obtained by diversion from the Chowan River Basin which is outside of the North Atlantic Region.

Future Use

The public water supply needs for Area 21 have been projected to increase throughout the Study period together with the population, population served and per capita income. The 2020 public water supply requirements will be 429 m.g.d. (EQ), 515 m.g.d. (NE), and 520 m.g.d. (RD). The estimated population served in 2020 will be 2,208,000 (EQ), and 2,603,000 (NE & RD) while the per capita income is expected to grow to $10,118 (EQ), $11,802 (NE), and $12,117 (RD).

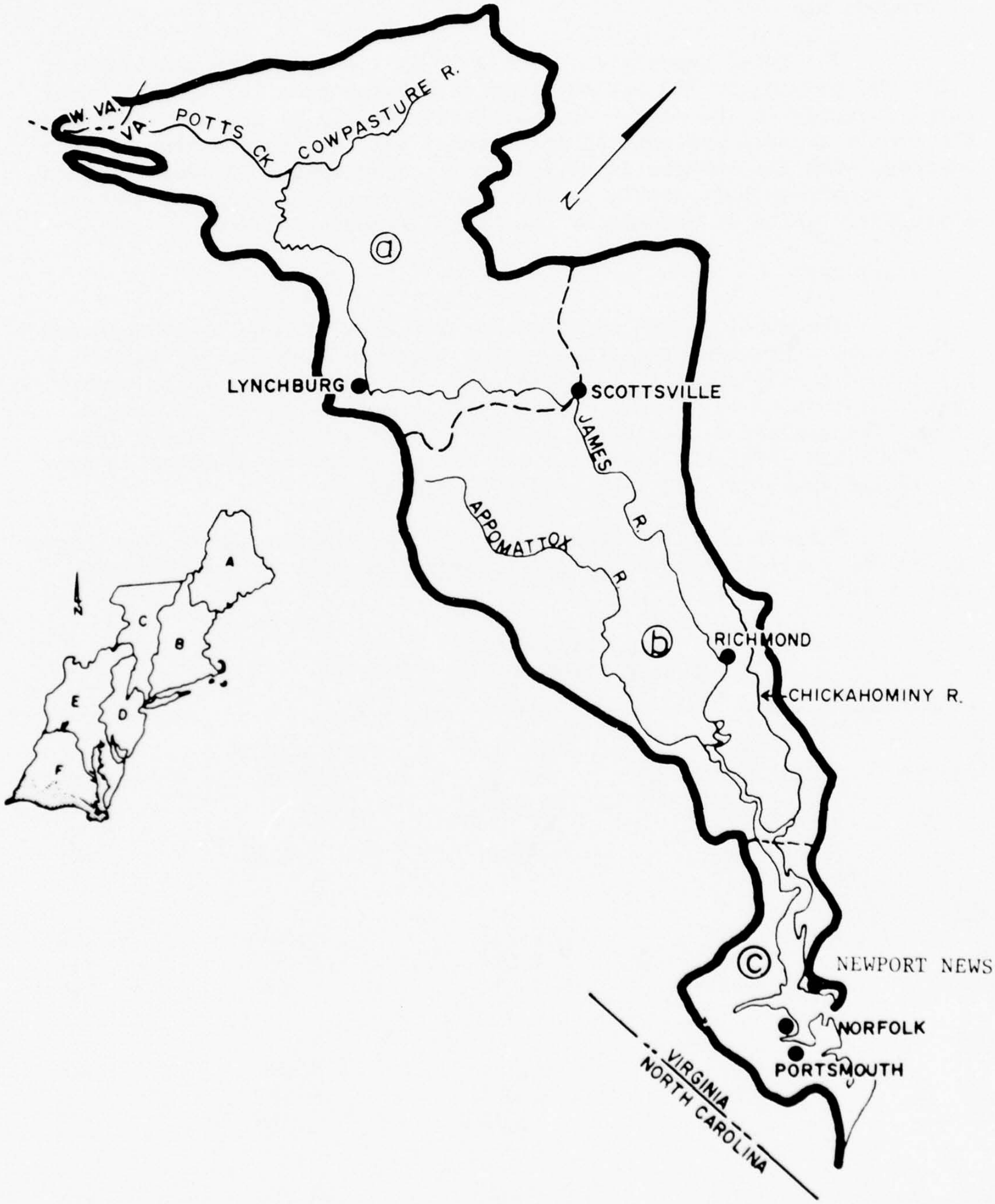
Present and projected population, population served, per capita income and public water supply requirements for Area 21 are shown in Table R-103.

TABLE R-103
PUBLIC WATER SUPPLY - AREA 21

OBJECTIVE	TOTAL POPULATION (1,000s)	POPULATION SERVED (1,000s)	PER CAPITA INCOME (Dollars)	PUBLIC WATER (m.g.d.)
Present	1,698	1,343	2,431	185
1980				
EQ	1,990	1,512	3,602	228
NE	2,057	1,632	3,785	247
RD	2,057	1,632	3,887	249
2000				
EQ	2,372	1,897	6,020	323
NE	2,584	2,078	6,695	359
RD	2,584	2,078	6,876	363
2020				
EQ	2,726	2,208	10,118	429
NE	3,199	2,603	11,802	515
RD	3,199	2,603	12,117	520

FIGURE R-26

AREA 21 JAMES RIVER BASIN



Future Devices and Costs

The future public water supply needs in Area 21 can be met by providing additional reservoir storage in 2000, and wells, treatment plant capacity, intakes and pumping stations for all time frames of the Study period. Additional diversion from the Chowan River Basin can be expected in 2000 and 2020.

Devices that could meet the incremental increases in public water supply and their estimated costs are shown in Table R-104. Storages listed include those necessary to maintain diversion flows.

TABLE R-104
PUBLIC WATER SUPPLY DEVICES AND COSTS - AREA 21
(Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Storage	-	-	-	-	-	-
Treatment Plant	29	28.40	41.8	38.10	43.1	40.40
Intake & Pumping	19.2	.10	27.6	.15	28.5	.15
Diversion	-	-	-	-	-	-
Ground Water	2.6	.08	3.7	.11	3.8	.11
2000						
Storage	71,000	23.30	75,000	25.20	76,000	25.40
Treatment Plant	96.6	68.40	114.1	77.50	116	78.70
Intake & Pumping	41.6	.23	49.1	.27	50.0	.27
Diversion	18.0	8.00	29.0	11.00	30.0	11.00
Ground Water	5.6	.29	6.7	.20	6.8	.21
2020						
Storage	-	-	-	-	-	-
Treatment Plant	129.3	89.90	189.4	122.40	190.9	123.40
Intake & Pumping	53.3	.29	78.4	.42	78.9	.43
Diversion	18.0	8.00	31.0	11.00	31.0	11.00
Ground Water	6.3	.19	9.3	.29	9.3	.29

Note: Storage quantities in acre-feet; devices in m.g.d.

SELF-SUPPLIED INDUSTRIAL WATER

Present Use

The total industrial water intake in Area 21 is 454 m.g.d., of which 397 m.g.d. are self-supplied, 21 m.g.d. are publicly-supplied and 36 m.g.d. are brackish. The two largest users of self-supplied water in the Area are the chemical and paper industries with respective intakes of 265 m.g.d. and 106 m.g.d. Eight other industries use self-supplied water, with intakes of less than 10 m.g.d. The chemical industry uses 24 m.g.d., the bulk of the brackish water intake.

Future Use

The projected growth of the Area is reflected in the anticipated increase in industrial water needs. The total industrial water intake in 2020 is expected to be 1,606 m.g.d. (EQ), 1,812 m.g.d. (NE) and 2,007 m.g.d. (RD), of which 1,405 m.g.d., 1,581 m.g.d. and 1,753 m.g.d., respectively, will be self-supplied.

The chemicals and paper industries will continue to be the major users of self-supplied fresh water, as shown in Table R-105.

TABLE R-105
2020 INDUSTRIAL SELF-SUPPLIED FRESH WATER REQUIREMENTS - AREA 21
(m.g.d.)

	OBJECTIVE		
INDUSTRY	EQ	NE	RD
Chemicals	630	710	787
Paper	541	609	676
Primary Metals	73	82	91
Food	52	58	64
Glass and Clay	36	40	45
Electrical Equipment	15	17	19
Machine Equipment	12	14	15
Transportation Equipment	9	10	11
Metal Products	9	10	11

The brackish water will be used mainly by the chemicals, food, primary manufacturing, and glass and clay industries.

Area 21's present and projected industrial water requirements are shown in Table R-106.

TABLE R-106
INDUSTRIAL WATER SUPPLY - AREA 21
(m.g.d.)

OBJECTIVE	TOTAL INTAKE	SELF-SUPPLIED FRESH	PUBLICLY-SUPPLIED FRESH	WASTE WATER	BRACKISH WATER	CONSUMPTIVE USE
Present	454	397	21	0	36	35
1980						
EQ	837	738	41	0	58	65
NE	837	738	41	0	58	65
RD	860	758	44	0	58	68
2000						
EQ	1,308	1,152	75	0	81	105
NE	1,384	1,218	80	0	86	111
RD	1,477	1,297	85	0	95	117
2020						
EQ	1,606	1,405	98	0	103	136
NE	1,812	1,581	111	0	120	154
RD	2,007	1,753	124	0	130	171

Future Devices and Costs

Self-supplied industrial water in Area 21 is presently obtained from river and/or lake intakes, brackish sources and wells. It is expected that the future needs will be met in a similar manner.

Table R-107 indicates devices that could satisfy the incremental increases in self-supplied industrial water and their estimated costs.

TABLE R-107
INDUSTRIAL WATER SUPPLY DEVICES AND COSTS - AREA 21
(Quantities in m.g.d.; Costs in millions of dollars)

DEVICE	OBJECTIVE					
	EQ		NE		RD	
	Quantity	Total Cost	Quantity	Total Cost	Quantity	Total Cost
1980						
Fresh Water						
Intake & Pumping	331	1.79	331	1.79	350	1.89
Brackish Water						
Intake & Pumping	22	.12	22	.12	22	.12
Ground Water	10	.31	10	.31	11	.34
2000						
Fresh Water						
Intake & Pumping	401	2.17	465	2.51	523	2.82
Brackish Water						
Intake & Pumping	23	.12	28	.15	37	.20
Ground Water	13	.40	15	.47	16	.50
2020						
Fresh Water						
Intake & Pumping	245	1.32	352	1.90	442	2.39
Brackish Water						
Intake & Pumping	22	.12	34	.18	35	.19
Ground Water	8	.25	11	.34	14	.44

CHAPTER 5. RURAL DOMESTIC AND LIVESTOCK WATER REQUIREMENTS

The estimated total present and projected water withdrawal for 1980, 2000 and 2020 in rural areas for use in rural homes or consumption by livestock are presented in this Chapter. Irrigation water was not considered since it is covered in Appendix I, Irrigation.

Alternative needs were not developed for rural water supply. Changes in annual product and livestock numbers are expected to be slight under the three NAR Study objectives. The rural population is dependent upon the population served used for developing public water supply needs, and will be the same under the NE and RD objectives. The EQ objective rural population variations are small and would not significantly affect the rural domestic water requirements.

The water sources may be reservoirs, springs, cisterns, wells or streams running through fields where livestock graze. No attempt was made to specifically identify water sources as ground water or surface water.

METHODS AND ASSUMPTIONS

LIVESTOCK WATER WITHDRAWAL

The livestock population for each of the 21 NAR Areas was determined from the Agricultural Census Reports for the years 1949, 1954, 1959 and 1964. These data were used as the basis of computing the water requirements for all livestock except dairy cows and chickens. The water requirements for dairy cattle and laying hens were based on the water requirements for dairy cattle and laying hens were based on the water required to produce a specific unit of the product. The number of units was determined from farm product sales in each of the 21 Areas. Water-use rates per animal, or requirements per unit of product, were based on published reports.

The withdrawal per head of livestock in gallons per day (g.p.d.) for the following animals was: Beef cows - 10, Hogs - 3, Sheep - 2, Chickens - .04 and Turkeys - .06.1/ The water requirements to produce milk and eggs were: .78 gallons per pound of milk, and .22 gallons per egg.2/ The projected water requirements were based on the projection of the livestock populations and of milk and egg sales at the farm from historical data for each of the 21 Areas.

1/ Estimated Use of Water in the United States, 1960, Geological Survey Circular 456, U. S. Department of the Interior.

2/ Agricultural Water Requirements of the Susquehanna River Basin with Projections to 2020, John R. Parks, Economic Research Service U. S. Department of Agriculture, June 1967, Table 7.

RURAL DOMESTIC WATER WITHDRAWAL

The rural domestic water requirement is that water used in households in rural areas that is self-supplied. Per capita consumption rates were utilized in the computation of gross water requirements. The population used to determine the rural domestic water requirement for each of the 21 Areas is shown in Table R-108. Farm and non-farm populations were not aggregated.

The daily per capita consumption of water used in this report is 55 gallons for the base year of 1964.3/ The 55 g.p.d. capita use was increased to 74 g.p.d. for 1980 and 95 g.p.d. for 2000.4/ Further increases were not considered since water saving will likely become more important and home appliances will be constructed with this in mind. The projected rural domestic water withdrawal is a function of changing per capita use and changing population.

WATER WITHDRAWALS BY SUB-REGION

Rural domestic and livestock requirements for 1964, 1980, 2000 and 2020 are shown in Tables R-109 and R-110, respectively, and combined in tables appear at the end of this chapter on pages R-154 through R-156. A substantial increase of rural water use in all Sub-regions is indicated through the year 2000. Only Sub-regions E and F show increases beyond 2000. Livestock uses affect the total water requirement only slightly as domestic use is the dominant factor.

The domestic water use is dependent upon the population and per capita use figures. Per capita use is anticipated to increase until the year 2000, after which it is expected to remain steady. This increase is due to more items being owned or developed which will use water, such as washing machines, dishwashers, multiple-bathroom homes, and two or three-car families. While the total population of the NAR is projected to increase considerably throughout the Study period, the population used to determine rural domestic water does not increase at the same rate. This is due to the fact that more and more people will be served by central water supplies in the future. Only in Sub-regions E and F are there increases in population after the year 2000, which accounts for the increase in total rural water requirements for those two Sub-regions beyond the year 2000.

The use of water by livestock showed only a slight increase

3/ The 55 gallons was midway between 60 gallons per day reported in Footnote 1/ and 50 gallons per day reported in Footnote 2/. The 10 gallons per day are reported in Footnote 1/.

4/ As reported in the Susquehanna Report, Footnote 2/.

TABLE R-108
POPULATIONS
(Thousands)

	1964		1980		2000		2020	
	Total	Rural	Total	Rural	Total	Rural	Total	Rural
Area 1	109	71	118	71	138	76	161	80
Area 2	147	40	159	39	186	34	219	23
Area 3	154	37	167	34	188	35	217	34
Area 4	163	14	175	14	188	13	220	13
Area 5	162	62	175	62	205	69	240	72
SUB-REGION A	735	224	794	220	905	227	1,057	222
Area 6	488	89	579	93	734	101	917	83
Area 7	914	56	1,008	50	1,288	39	1,578	32
Area 8	1,679	234	1,876	244	2,286	252	3,002	210
Area 9	4,939	141	5,740	114	7,089	142	8,708	88
Area 10	2,062	343	2,551	356	3,360	352	4,105	265
SUB-REGION B	10,082	863	11,754	857	14,757	886	18,310	678
Area 11	533	176	588	173	677	162	793	160
Area 12	2,136	579	2,643	622	3,672	644	5,068	485
Area 13	11,083	375	12,241	411	13,778	312	15,490	155
SUB-REGION C	13,752	1,130	15,472	1,206	18,127	1,118	21,351	800
Area 14	4,387	263	5,192	257	6,720	274	8,428	220
Area 15	6,719	721	7,804	918	9,610	1,077	11,853	987
Area 16	760	44	1,082	49	1,707	52	2,290	56
SUB-REGION D	11,866	1,028	14,078	1,224	18,037	1,403	22,571	1,263
Area 17	3,362	735	3,903	750	4,902	751	6,097	680
Area 18	2,330	539	2,767	618	3,445	778	4,261	869
SUB-REGION E	5,692	1,274	6,670	1,368	8,347	1,529	10,358	1,549
Area 19	3,236	700	4,434	946	6,338	1,128	8,627	1,110
Area 20	316	170	382	196	518	254	737	347
Area 21	1,698	355	2,057	425	2,584	506	3,199	596
SUB-REGION F	5,250	1,225	6,873	1,567	9,440	1,888	12,563	2,053
TOTAL NAR	47,377	5,744	55,641	6,442	69,613	7,051	86,210	6,565

for the total Region and most of this was accounted for in Sub-region E. Other Sub-regions show little change.

Constant animal consumption rates were assumed for all classes of livestock except dairy cows and laying hens. The total water requirements for the production of eggs and milk would be influenced by the increased production of these items. The increased use of water shown in the analysis is a result of the increased egg, milk and broiler production. The population of other species of livestock was estimated to remain relatively stable based on the 1940 and 1964 historical data.

WATER WITHDRAWALS BY AREA

As in the case of the Sub-regions, an increase in rural water-use is indicated in all Areas up to the year 2000, except for a slight decline in Area 13. After the year 2000, only Areas 4, 5, 11, 16, 18, 20 and 21 show increases in rural water use. These Areas are predominantly rural in nature and the transition to central water supply system is expected to take a longer period of time compared to Areas where there is a large degree of urbanization. Livestock uses affect rural water use only slightly, with minor increases in livestock use expected for most Areas. The only exception are the more urbanized Areas, where irrigation, industrial and urban domestic needs for water are presently the greatest, and are likely to increase more than in any other Area. This competition for the water resource is graphically illustrated in Figures 1 through 6 in Appendix I, Irrigation. Note that the Areas of high irrigation concentration are Areas of high urban and rural non-farm growth.

Though the rural water use in most of the 21 Areas will greatly increase in the projected years, it is not expected to become a problem. Except for the rural areas in close proximity to the urban areas, there is not a great deal of competition for supplies.

Much of the rural water is withdrawn near the sources of water supply at the headwaters of the rivers or in upstream areas. Much of the supply, also, is ground water that normally replenishes itself seasonally. That is not to say that upstream and/or rural use of water is not important in that this is the source of water supply for urban areas. Its use upstream will influence the quality and quantity of water downstream and may impact on fish and wildlife resources.

Of greater concern in future periods will be pollutants to rural streams and ground water aquifers due to inadequate septic systems from rural non-farm development. Soil survey reports developed by the Soil Conservation Service of the U. S. Department of Agriculture should be utilized in the development of policies and regulations for control. Also, agricultural pollutants from livestock feedlots have become of considerable concern. The nature and extent of this problem

have not been adequately assessed; however, research is being conducted by the Agricultural Research Service of the U. S. Department of Agriculture.

TABLE R-109
ANNUAL RURAL DOMESTIC WATER REQUIREMENTS
(Million Gallons)

	1964	1980	2000	2020
Area 1	1,425	1,918	2,635	2,774
Area 2	803	1,053	1,179	798
Area 3	743	918	1,214	1,179
Area 4	281	378	451	451
Area 5	1,244	1,675	2,393	2,497
SUB-REGION A	4,496	5,942	7,872	7,699
Area 6	1,787	2,512	3,502	2,878
Area 7	1,124	1,351	1,352	1,110
Area 8	4,698	6,590	8,738	7,281
Area 9	2,831	3,079	4,924	3,051
Area 10	6,886	9,616	12,206	9,189
SUB-REGION B	17,326	23,148	30,722	23,509
Area 11	3,533	4,673	5,617	5,548
Area 12	11,623	16,800	22,331	16,817
Area 13	7,528	11,101	10,819	5,375
SUB-REGION C	22,684	32,574	38,767	27,740
Area 14	5,280	6,942	9,501	7,629
Area 15	14,474	24,795	37,345	34,224
Area 16	883	1,323	1,803	1,942
SUB-REGION D	20,637	33,060	48,649	43,795
Area 17	14,755	20,258	26,041	23,579
Area 18	10,820	16,692	26,977	30,132
SUB-REGION E	25,575	36,950	53,018	53,711
Area 19	14,053	25,551	39,113	38,489
Area 20	3,413	5,293	8,807	12,032
Area 21	7,127	11,479	17,546	20,666
SUB-REGION F	24,593	42,323	65,466	71,187
TOTAL NAR	115,311	173,997	244,494	227,641

TABLE R-110
ANNUAL LIVESTOCK WATER REQUIREMENTS
(Million Gallons)

	1964	1980	2000	2020
Area 1	3	2	2	2
Area 2	173	211	259	275
Area 3	370	449	508	529
Area 4	279	302	311	322
Area 5	248	320	369	381
SUB-REGION A	1,073	1,284	1,449	1,509
Area 6	329	347	359	371
Area 7	640	694	750	776
Area 8	1,095	1,008	895	920
Area 9	523	537	565	589
Area 10	921	862	929	957
SUB-REGION B	3,508	3,448	3,498	3,613
Area 11	2,725	2,918	3,191	3,324
Area 12	3,491	3,775	4,147	4,316
Area 13	20	23	25	25
SUB-REGION C	6,236	6,716	7,363	7,665
Area 14	343	45	2	2
Area 15	3,698	3,413	3,497	3,612
Area 16	206	105	88	90
SUB-REGION D	4,224	3,563	3,587	3,704
Area 17	7,857	9,391	10,422	10,824
Area 18	2,103	2,549	2,876	3,032
SUB-REGION E	9,960	11,940	13,298	13,856
Area 19	3,626	4,122	4,560	4,711
Area 20	567	598	626	639
Area 21	914	914	978	974
SUB-REGION F	5,107	5,660	6,164	6,324
TOTAL NAR	30,108	32,611	35,359	36,671

TABLE R-111
ANNUAL RURAL DOMESTIC AND LIVESTOCK WATER REQUIREMENTS
(Million Gallons)

	1964	1980	2000	2020
Area 1	1,428	1,920	2,637	2,776
Area 2	976	1,264	1,438	1,073
Area 3	1,113	1,367	1,722	1,708
Area 4	560	680	762	773
Area 5	1,492	1,995	2,762	2,878
SUB-REGION A	5,569	7,226	9,321	9,208
Area 6	2,116	2,859	3,861	3,249
Area 7	1,764	2,045	2,102	1,886
Area 8	5,793	7,598	9,633	8,201
Area 9	3,352	3,616	5,489	3,640
Area 10	7,807	10,478	22,135	10,146
SUB-REGION B	20,834	26,596	34,220	27,122
Area 11	6,258	7,591	8,808	8,872
Area 12	15,114	20,575	26,478	21,133
Area 13	7,548	11,124	10,844	5,400
SUB-REGION C	28,920	39,290	46,130	35,405
Area 14	5,623	6,987	9,503	7,631
Area 15	18,172	28,208	40,842	37,836
Area 16	1,089	1,428	1,891	2,032
SUB-REGION D	24,861	36,623	52,506	47,499
Area 17	22,612	29,649	36,463	34,403
Area 18	12,923	19,241	29,853	33,164
SUB-REGION E	35,535	48,890	66,316	67,567
Area 19	17,679	29,673	43,673	43,200
Area 20	3,980	5,891	8,433	12,671
Area 21	8,041	12,393	18,524	21,640
SUB-REGION F	29,700	47,983	71,630	77,511
TOTAL NAR	145,419	206,608	279,853	264,312

CHAPTER 6. DESALTING AS A WATER SUPPLY SOURCE

Desalting as a technique in water supply has not been used in this relatively water rich area because its monetary and associated environmental costs are high when compared to more conventional surface or ground water sources. Nevertheless this technology is applicable in some parts of the N.A.R. and its future costs competetive with conventional sources.

The conversion of sea or brackish water to fresh is not a new idea. Aristotle in the fourth century B.C. described how to boil saltwater and condense the steam to release fresh water. However, the world's demand for desalted water to supplement rain supplies did not arrive until the second half of the present century. The world's population was exploding; the amount of naturally-produced potable water remained constant. The collision between these trends was in sight.

A significant aspect of desalting is its capability to provide a completely controllable new souce of freshwater that isn't subject to the whims of nature. Furthermore, it is a source not complicated by many of the institutional constraints that often exist with interbasin transfer, or with local diversions. Its flexibility permits it to be located near the area of need with units added as the demand increases. This permits it to be used as a firm supply, as an interim supply until large surface water supply systems can be put into operation, and as a conjunctive supply to increase the firm yield of an existing system. The several processes available make it possible to use feedwaters with salinities ranging from a few thousand parts per million (p.p.m.) to that of seawater (35,000 p.p.m.). Thus the best use can be made of the local available feedwater.

THE SALINE WATER CONVERSION PROGRAM

President Truman noted the water problem in his 1950 budget message: "Experience in recent years has been that it may not be possible to meet the shortages of water, which are a threat in some areas, through our extensive water resources programs. I recommend, therefore, that the Congress enact legislation authorizing the initiation of research to find the means for transferring saltwater into freshwater in large volume at economical costs." Several bills relating to saline water conversion were introduced following the President's budget message, but it was not until 1952 that a bill introduced by the late Senator (then Representative) Clair Engle of California was enacted into law.

This first legislation authorized a five-year program to develop practical low-cost means of producing from seawater, or other saline waters, water of a quality suitable for agricultural, industrial, municipal, and other beneficial consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis. Under provisions of this act, the Secretary of the Interior established the Office of Saline Water (OSW) to develop new or improved conversion processes by

means of research grants and contracts; to conduct research and technical development work; to make careful engineering studies to ascertain the lowest investment and operating costs; and to determine the best plant designs and conditions of operation. The law was amended a number of times to increase the authorization, and expand and extend the program of the OSW.

In 1958, the Congress enacted a Joint Resolution, introduced by Senator Clinton P. Anderson of New Mexico, authorizing the Department of the Interior to construct not less than five saline water conversion plants to demonstrate the reliability, engineering, operating, and economic potentials of the most promising sea or brackish water conversion processes. Three of these plants were to convert seawater to fresh, while two would utilize brackish waters from inland areas. Five such plants were constructed.

Perhaps the best known of these was the 1 m.g.d. multistage flash distillation plant at San Diego, California. After operating successfully for nine days less than two years, this plant was dismantled and moved to the Naval Base at Guantanamo Bay, Cuba, to help provide fresh water for that installation. It has been replaced by an improved technology, 1 m.g.d. distillation plant at San Diego. At Freeport, Texas, the Office of Saline Water constructed a long-tube vertical distillation plant capable of producing 1 m.g.d. of fresh water from the sea. A third distillation plant, using a forced-circulation, vapor-compression process, converts brackish water to 1 m.g.d. of fresh water at Roswell, N.M. Also operating on brackish water is a 250,000-gallons-per-day (g.p.d.) electrodialysis plant at Webster, S.D.

As a result of an accelerated program authorized in 1965, OSW undertook to develop desalting technology applicable to large plants. The multistage flash module at San Diego, shown in Figure R-27, is the first experimental desalting unit specifically designed to provide engineering and operating data for the multimillion gallons-per-day desalting plants that will be required in some areas of the world during the 1970's. It offers engineers the opportunity to confirm essential process parameters and structural designs that will be utilized in the efficient and economical design, construction and operation of very large desalting plants. Though it is only a slice or a portion of a 50 m.g.d. multistage flash distillation process desalting plant, the module simulates the operation of a full plant.

In August 1970, OSW announced a Memorandum of Understanding for the development of a module system in Orange County, Cal. that will combine the vertical tube evaporator and multistage flash processes. The module will establish the technology necessary to construct and guarantee the performance of plants up to 200 m.g.d. and will serve as the basic element for scale up to larger size prototypes. It is planned that construction of the module will begin in the summer of 1971.

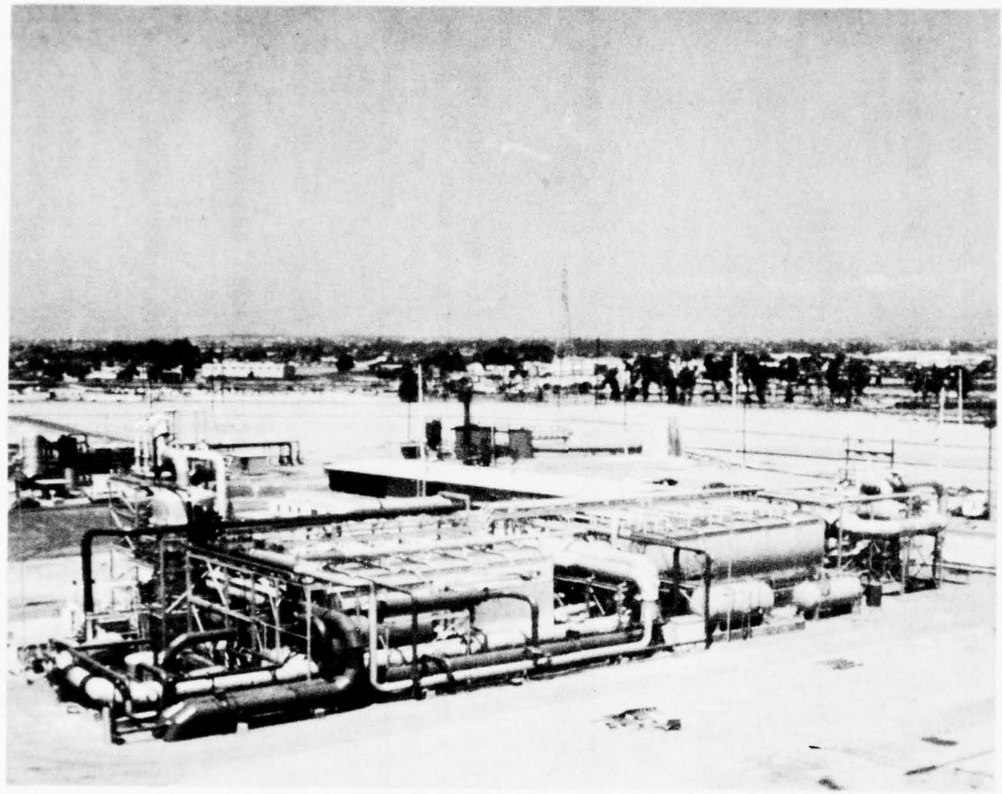


FIGURE R-27. MULTISTAGE FLASH EVAPORATOR MODULE AT SAN DIEGO, CALIFORNIA

DESALTING PROCESSES AND ENERGY SUPPLY

APPLICABLE PROCESSES

The choice of a desalting process for application to a particular saline water supply is generally based on minimum cost. Many factors need to be considered in arriving at a choice, including:

- Salt concentration and composition of the feedwater.
- Maximum acceptable concentration of salt in product water.
- Difficulty in disposing of waste brines.
- Commercial status of the process.
- Size and location of plant.
- Type of energy sources available.
- Type of operating and maintenance personnel available at the site.

Desalting processes in commercial use are of three general kinds: distillation processes, including multistage flash (MSF) plants, vertical-tube evaporators (VTE), and vapor compression (VC) process used in combination with VTE, MSF or other variations of distillation; membrane processes, including electrodialysis (ED) and reverse osmosis (RO); and freezing processes (VF).

The distillation processes have been most widely used throughout the world in desalting plants for seawater or the most concentrated brines, while membranes have been used generally for brackish waters with less than 5,000 p.p.m. of dissolved solids. The distillation processes produce a high-purity product of 5 to 25 p.p.m. dissolved solids. ED product water generally is produced with about 500 p.p.m. of dissolved solids and RO product water about 500 p.p.m. depending on the choice of membrane. Distillation product water has the potential use of blending with other supplies to improve water quality. The distillation plant waste stream is generally concentrated to 7% to 10% salt, while the membrane process waste stream usually contains only about 0.5% to 2% salt.

The most extensively used process, at present, is MSF distillation. Plants using this process are commercially available to approximately 10 m.g.d. capacity. Currrently, there is considerable emphasis on the development of VTE, RO, and combination processes. These may therefore be of greatest interest for the large desalting

plant applications of the future.

Membrane process plants can readily be located wherever electric power is available, provided that feedwater does not exceed about 10,000 p.p.m. of salt. Distillation plants require a source of steam to heat the water. The steam may be supplied by coal, oil, gas-fired or nuclear boilers, by large power plants for dual-purpose use in producing electricity and desalted water, or by vapor compressors. The latter are driven by electric motors, steam or gas turbines, or diesels. Electrodialysis process plants for 1.2 m.g.d. have been built and are in operation. A reverse osmosis plant of 150,000 g.p.d. is in operation.

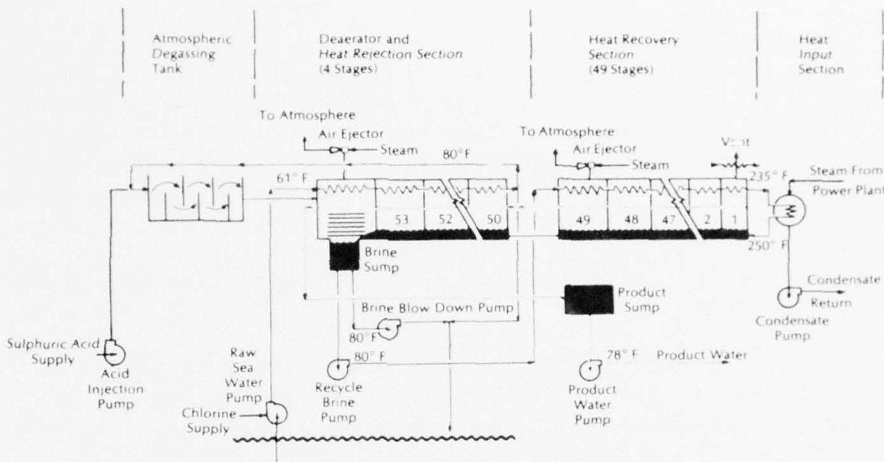
The cost of desalted water varies considerably depending on plant location, size, type of desalting process, financing and many other variables. Current commercial plants of 1 to 3 m.g.d. capacity produce water in the general cost range of $1 per 1,000 gallons. Studies of large nuclear-powered, dual-purpose plants indicate that costs of 20¢ to 40¢ per 1,000 gallons may be achieved in the 1980s. Collection and water conveyance costs could add another 5¢ to 10¢ per 1,000 gallons.

DISTILLATION PROCESSES

Most water desalting plants in recent years have used the multistage flash (MSF) distillation process, and consequently this is the most thoroughly proven method of producing desalted water. Recent developments in improved heat transfer tubing for use in vertical-tube evaporator (VTE) plants promise economic advantages to these plants, however. Another recent development in VTE conceptual designs has been the use of the MSF evaporator to recover the heat from the brine and product streams and heat the incoming feed stream. This approach has the advantage of reducing the cost of heat recovery surfaces. Vapor compression (VC) distillation is a well established desalting process that is particularly applicable to requirements for compact, low marine applications and for several land-based desalters in the range of 20,000 g.p.d. to 1 m.g.d.

MSF Process

The MSF distillation process makes use of the fact that water boils at progressively lower temperatures as it is subjected to progressively lower pressures. The process is illustrated in Figure R-28. Seawater is heated and then introduced into a chamber where the pressure is sufficiently low to cause some of the water to boil instantly, or "flash" into steam. Vaporization of some of the water results in a lowering of temperature of the remaining brine. The brine then flows into the next chamber where the pressure is lower than in the previous chamber, more of the water flashes into steam, and the temperature is again reduced. Condensation occurs when the steam



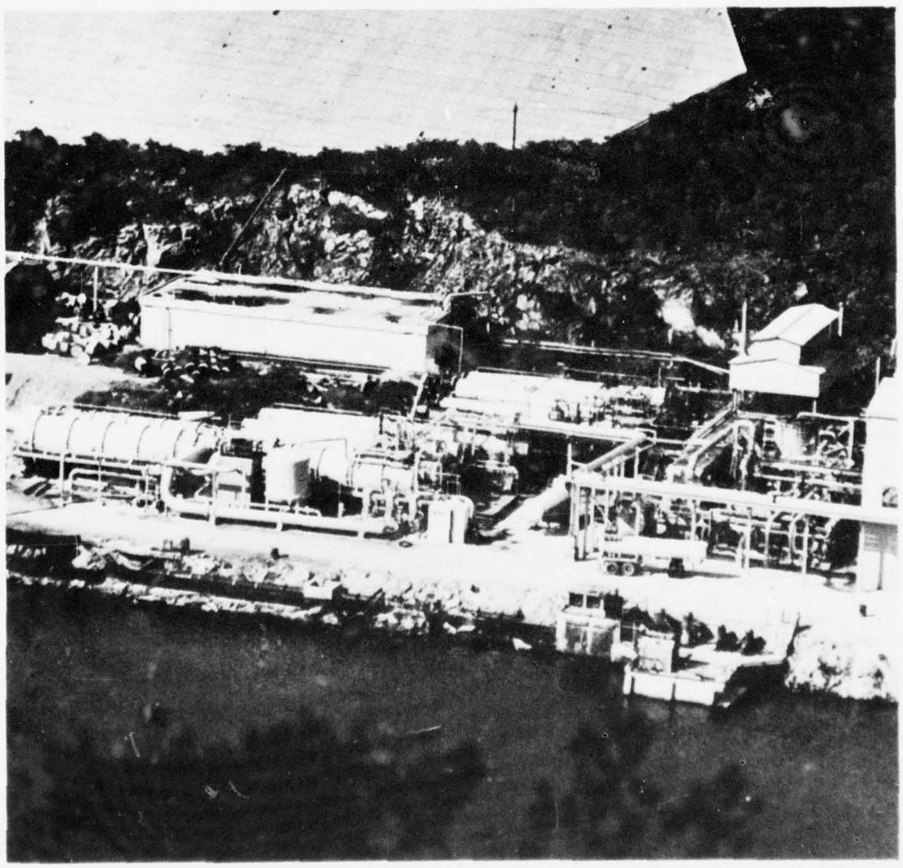


FIGURE R-28. MULTISTAGE FLASH EVAPORATOR PROCESS AND 3.7 M.G.D. FACILITY AT ST. THOMAS, VIRGIN ISLANDS

comes into contact with the heat exchanger through which the incoming saltwater flows before passing through the brine heater. In this way, the heat which must be removed from the steam in order to condense it into freshwater is transferred to the seawater, supplying it with some of the heat energy required to cause it to boil.

VTE Process

The diagram shown in Figure R-29 illustrates the long-tube vertical distillation process. The saltwater falls through a bundle of long metal tubes located inside a large chamber. As the saltwater falls through the tubes, it is heated by steam which surrounds the tubes. This heat exchange operation converts some of the water from the saline solution inside the tubes into steam, and, at the same time, condenses some of the steam which surrounds the tubes into fresh water.

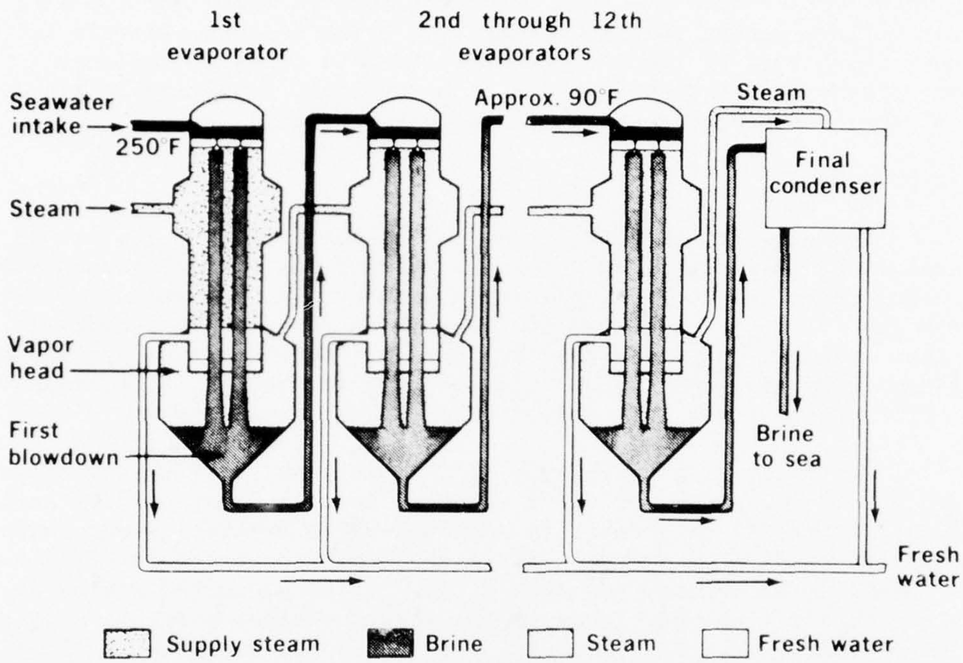
To obtain high efficiency in the utilization of heat energy, the process is repeated in several chambers which are arranged in series. The steam for the first chamber is supplied by an external steam source, and the condensed water from the first chamber is returned to the steam source plant to be reconverted into steam. Steam generated inside the tubes of the first chamber flows to the second chamber where it surrounds the second bundle of tubes. The brine that did not vaporize in the first chamber enters at the top of the second chamber and flows downward through the second tube bundle. The steam surrounding the tubes heats the brine as it falls, converting some of the water inside of the tubes into steam, and condenses on the outside of the tubes into fresh water.

This process is repeated through a number of chambers. The temperature of the saline water drops as it progresses through the series of chambers. The pressure in each chamber is also progressively reduced to permit vaporization to occur at lower temperatures. The brine which collects at the bottom of the last chamber is discharged.

MSF-VTE Process

In a combination multistage flash-vertical-tube evaporator (MSF-VTE) process plant, a section utilizing the MSF process is operated in conjunction with a VTE process section in such a way that the MSF section serves as a feedwater heater for the VTE section. Part of the seawater feed stream serves as coolant in the final condenser of the VTE section and then, mixed with additional seawater, is acidified, deaerated and pumped into the condenser tube bundles of MSF section. This feed progresses through the condenser tubes of all MSF stages, picking up heat as it condenses the steam. The feed finally enters the brine heater where its temperature is raised to a final temperature (approximately 260° F.).

The heated seawater is split so that a portion is admitted to



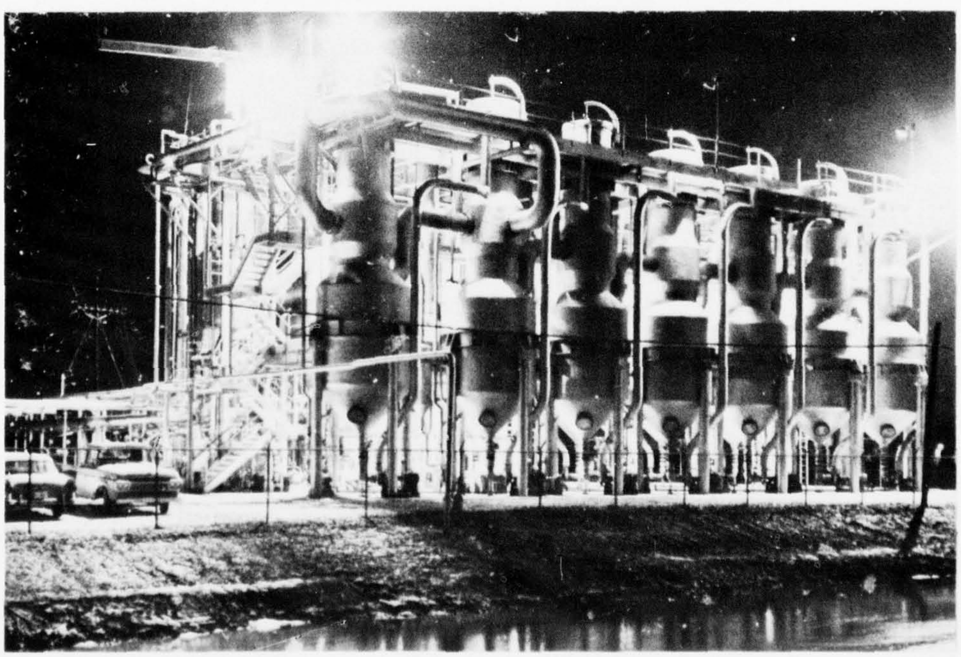


FIGURE R-29. VERTICAL TUBE EVAPORATOR PROCESS AND 1 M.G.D. TEST BED PLANT AT FREEPORT, TEXAS

the tubes of the first VTE effect and the remainder becomes the flashing brine steam in the MSF stages. Steam from an external steam source condenses on the tubes of the first VTE effect, vaporizing a comparable amount of the seawater. The brine from the first effect is delivered to the first MSF stage where it mixes with the balance of the seawater. Steam from the first effect is delivered to the second effect as in a normal VTE cycle. Brine flashes downstream in the MSF as in a normal MSF cycle. However, from certain stages, brine is withdrawn to feed the VTE effects operating at the same temperature as the MSF stages.

The process is repeated and continues through the last VTE effect to the final condenser and the condensate sent to an appropriate stage of the multistage flash (MSF) section. In this fashion all of the heat supplied to the first effect is passed as latent heat to the final condenser, each effect has the same heat duty, and there is virtually no gain or loss of heat between the vertical-tube evaporator (VTE) and MSF feed heater.

A flow diagram of the MSF-VTE process is illustrated in Figure R-30.

Vapor compression (VC)-VTE-MSF process

In a simple form, the VC process consists of a single-effect VTE with brine boiling inside the tubes or flashing above the tubes. The steam produced is pressurized and heated with a mechanical compressor, then condensed on the outside of the vertical tubes, thereby boiling more brine and producing desalted product water.

Most of the energy required by the process is used in the vapor compressor, and only a small amount of additional heat is required to offset losses from the equipment. Thus, the key economic factors in the process are the VC driver and the cost of its required fuel. It has recently been proposed that the VC process can be made more efficient by combining it with single- or multi-effect VTE and with MSF feed heating. The combined process flowsheet in its simplest form is shown schematically in Figure R-31. Seawater feed passes through the heat recovery tubes of the MSF and is heated to a temperature a few degrees below the operating temperature of the VC-VTE unit. Not shown on this diagram are the necessary acid treatment and the decarbonation for the prevention of alkaline scale deposition in the tubes of the MSF and of the VTE. After being preheated in the MSF, the seawater feed stream is fed to the VTE where it may be evaporated in one effect or in several effects.

MEMBRANE PROCESSES

The two principal types of membrane processes are electrodialysis (ED) and reverse osmosis (RO). These processes appear to have wide applications in treating brackish waters, those having lower

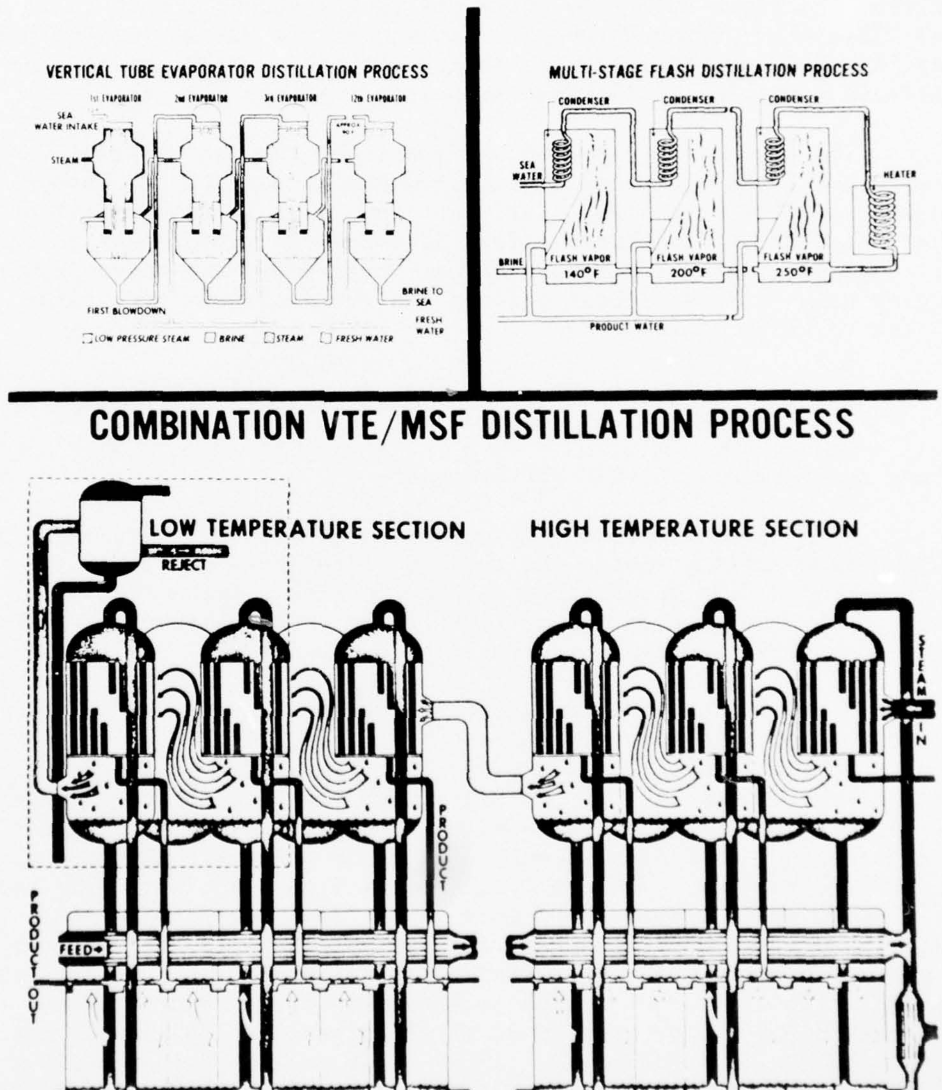


FIGURE R-30. COMBINATION VTE-MSF DISTILLATION PROCESS

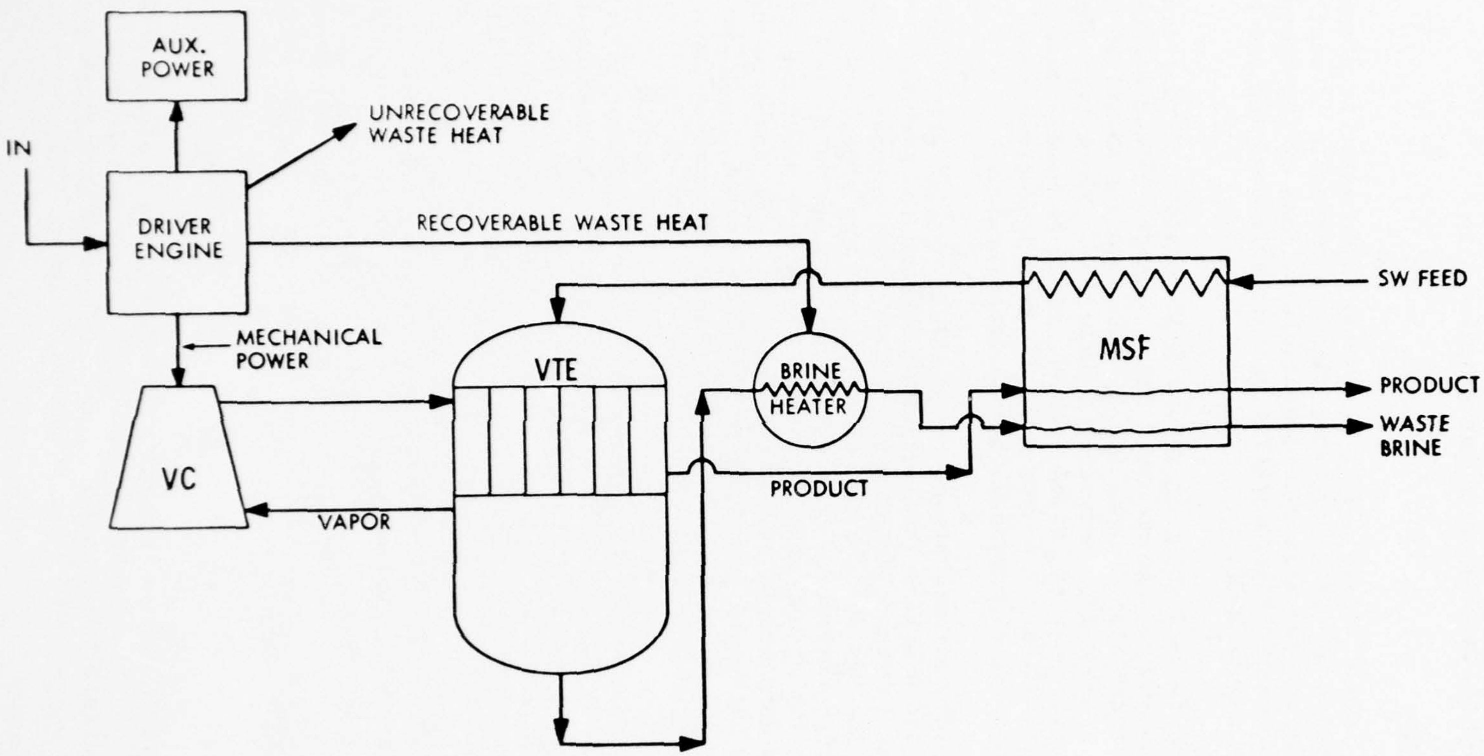


FIGURE R-31. VAPOR COMPRESSION-VERTICAL TUBE EVAPORATOR PROCESS
(Feed preheated by once-through MSF)

salinity than seawater. The principles involved in the two processes are described in the following paragraphs.

ED Process

Electrodialysis (D) is a process which extracts dissolved salts from water by using membranes that are permeable to positively or negatively charged ions and impermeable to ions of the opposite charge. A schematic representative of this salt-removing process is presented in Figure R-32.

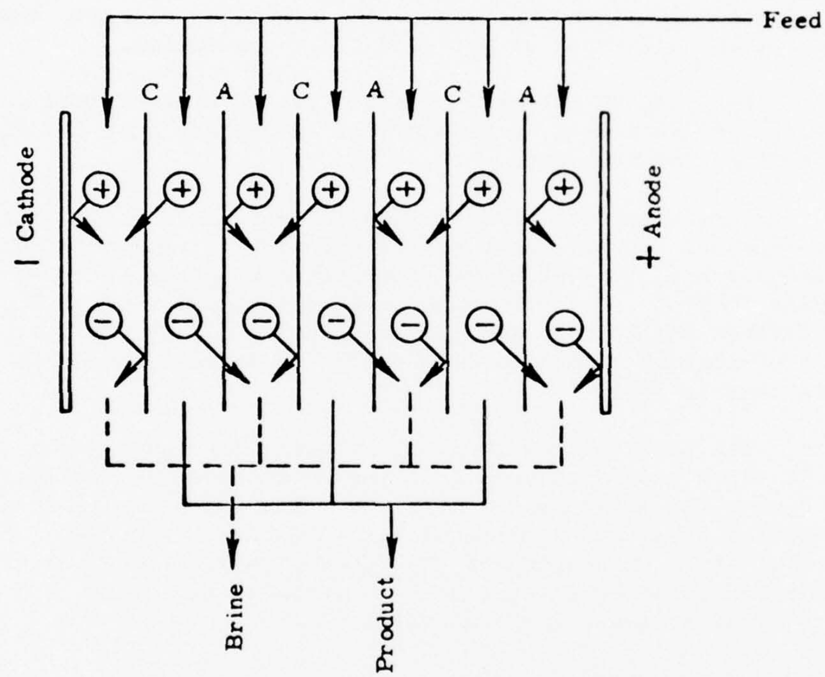
The ED cell shown in Figure R-32 consists of many ion exchange membranes stacked between an anode and a cathode. These membranes are defined alternately as C types and A types, and are separated by spacers which allow flow between the membranes. The C-type membrane is a conductive sheet of cation exchange resin permeable only to positive ions, while the A-type membrane is a conductive sheet of anion exchange resin permeable only to negative ions.

When a direct current potential is applied across the anode and cathode and a saline feed is pumped through the membrane stack, the positive ions in the solution migrate toward the cathode. These ions pass easily through the C-type membranes, but are stopped when they reach an A-type membrane. Likewise, negative ions in the solution migrate toward the anode, passing through the A-type membranes and being stopped when encountered by a C-type membrane. The ion concentration increases in alternate compartments which are called the brine passages. Simultaneously, the other compartments become depleted of ions. These are known as product passages.

It is possible to achieve the desired degree of purification in a single pass through a large stack. However, this causes undesirably large variations in current density within the stack. At the stack outlet, the differences in ionic concentration in the brine and product streams cause a greater overall stack resistance (and lower current density) than at the stack inlet, where the concentrations of the two streams are equal. To achieve minimum power utilization, desalination in an ED plant is usually achieved by placing several stacks in series. The brine and product outlet streams from each stack are injected into the inlets of the brine and product streams, respectively, of the subsequent stack. This facilitates a more uniform current density throughout any one stack and results in the most efficient usage of power supplied to each stack.

RO Process

Osmosis and reverse osmosis (RO), or the reversal of osmotic flow, depend on the existence of a membrane that is selective in the sense that certain components of a solution can pass through the membrane, while one or more other components cannot. This intrinsic



Legend

C = membrane permeable to positive ions only
A = membrane permeable to negative ions only
⊕ = any positive ion, such as Na^+
⊖ = any negative ion, such as Cl^-

FIGURE R-32. ELECTRODIALYSIS PROCESS DIAGRAM

property of a membrane is known as semipermeability. From the standpoint of desalination, the following explanation describes the phenomena of RO. Assume a semipermeable membrane which acts as the interface between containers, one containing relatively pure water and the other containing a salt solution. Under normal conditions water will flow from the pure container through the membrane and into the concentrated solution, thereby diluting the concentrated solution. This phenomenon is known as osmosis. The driving potential for the flow of pure water is known as osmotic pressure. The actual flow of fluid is related to the chemical potential of the solution. This chemical potential is a function of the solution pressure, temperature, and the number and types of molecules in the solution.

Applying an external pressure to the concentrated salt solution equal to the osmotic pressure will completely stop the flow of fluid through the membrane.

This condition of zero flow is known as osmotic equilibrium. If the external pressure on the salt solution is continued beyond the osmotic pressure, a reversal of flow will take place. Pure water will be separated from the concentrated salt solution. The resultant effect is to further concentrate the saline solution and to produce pure water. A pressure of 600 to 1000 p.s.i. is normally used for practical reverse osmosis (RO).

The principle of RO is illustrated in Figure R-33. The saltwater is first pumped through a filter where suspended solids that would damage the membranes are removed. The saltwater is then raised to operating pressure by a second pump and then introduced into the desalination unit. A portion of the water permeates the membranes and is collected as product water at the bottom of the unit. The brine is discharged at the top of the unit.

Freezing Processes

It has long been recognized that saline waters can be purified by various freezing processes. When a saline solution is frozen, fresh water ice crystals are formed, and the salts are concentrated in the remaining brine solution. The ice crystals can then be separated from the brine, washed, and melted to yield fresh water. Several water conversion processes utilizing a freezing step have been developed and investigated in pilot plants. These processes have used a variety of methods for freezing, including direct contact between the feedwater and a secondary insoluble refrigerant such as butane and refrigeration by absorption of the water vapor with lithium bromide solution. In probably the most sucdessful freeze process that has been developed to date, the saline water is cooled below its freezing point in one compartment by vacuum evaporation. The water vapor evolved in then compressed and condensed on the melting ice crystals in a separate compartment. As the vapor condenses, it gives up its heat of vaporization and this heat is absorbed by the ice in melting. The condensed vapors and melted ice form cold product water. A number of groups have carried out research on this so-called vacuum freeze-vapor compression (VFVC) process.

ENERGY SUPPLY

Distillation Processes

The primary energy requirement for plants of the multistage flash (MSF), vertical-tube evaporator (VTE), or combination MSF-VTE types is in the form of process steam having a saturation temperature below 300° F. In the case of water-only plants, this steam may come from low pressure steam generators, either fossil- or nuclear-fueled. In situations where there is a ready market for power in the area, significant savings accrue from combining the power and water producing functions into a dual-purpose plant, with power generated by backpressure steam turbines that exhaust steam at a pressure appropriate for use in the evaporators. In addition to the process steam requirement of about 1 pound of steam for 10 pounds of product, distillation plants require in the order of 0.2 MW/m.g.d. of energy for pumping, either in the form of electricity or shaft output from steam turbine drives.

The primary energy requirement for vapor compression (VC) plants is in the form of mechanical energy for driving the vapor compressor. This energy can be derived from electric motors, steam turbines, gas turbines, or gas/oil-fueled engines. If gas turbines or engines are used, a large part of the exhaust and cooling system heat can be profitably recovered and utilized in the evaporator process.

Membrane Processes

Energy requirements for the membrane processes are generally entirely electrical. Electrodialysis (ED) plants require approximately 5 kw.-hr./1,000 gal. of product per 1,000 p.p.m. of salt removed for the cells and 3 kw.-hr./1,000 gal. of product for pumping. Pumping energy required for RO plants varies with the recovery ratio (product/feed), ranging from approximately 17 to 10 kw.-hr./1,000 gal. product as the recovery ratio ranges from 0.5 to 0.9. It is possible to reduce the power requirement by up to 20% at the lower recovery ratio by using power recovery water turbines.

Freezing Processes

Energy requirements for a VFVC plant are entirely electrical. This energy comprises a major fraction of the costs for water production. Electrical power consumption is strongly dependent upon the feedwater temperature and salinity, and desalting unit size. Power requirements for conversion of seawater at 70°F are about 45 and 30 KWH/1,000 gallons of product for unit sizes of 0.1 and 0.5 MGD respectively.

USES AND DEVELOPMENTS IN DESALTING

INVENTORY OF DESALTING PLANTS

On January 1, 1970, there were 726 desalting plants of 25,000 g.p.d. capacity of greater in operation or under construction in the

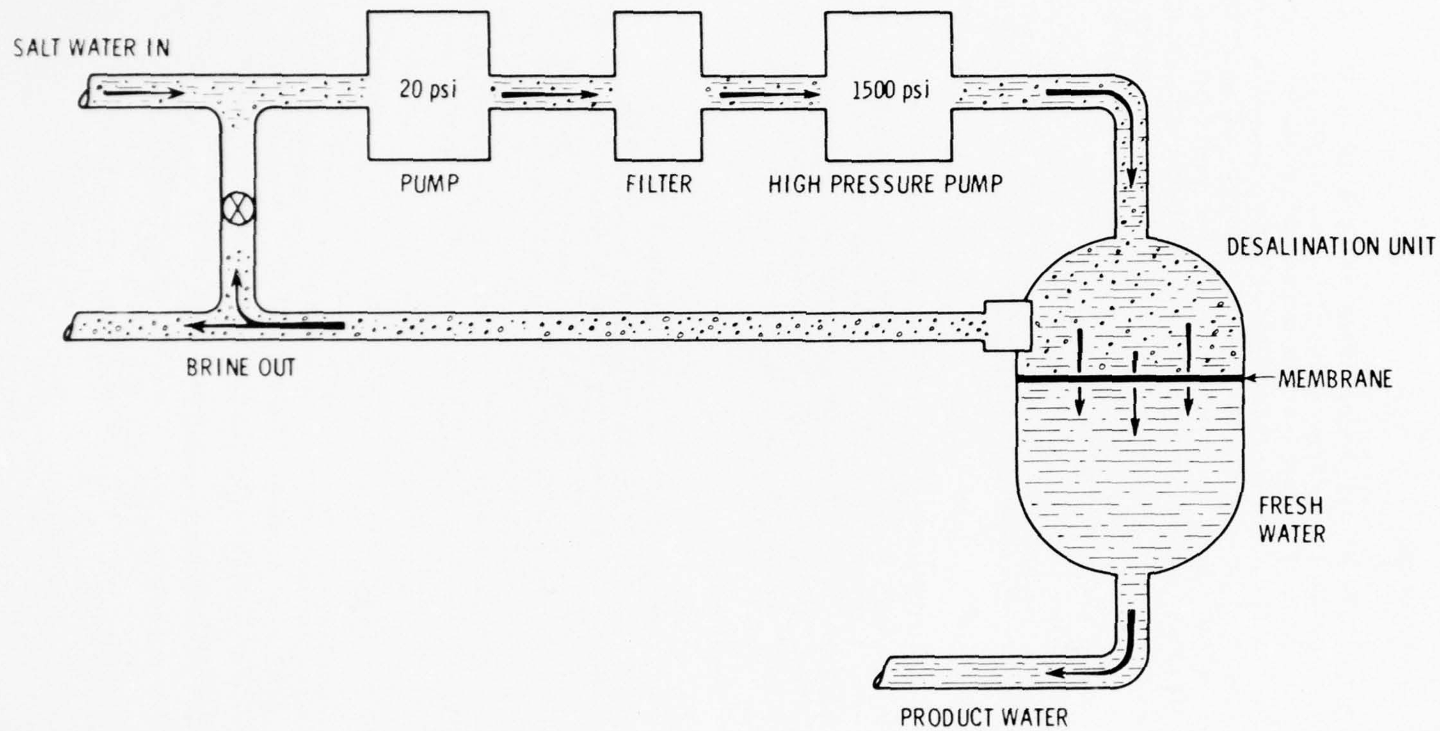


FIGURE R-33. REVERSE OSMOSIS PROCESS DIAGRAM

world, comprising a total capacity 271 m.g.d., as shown in Table R-112. Of these, 40 plants with a combined daily capacity of 24 m.g.d. represent new construction starts during 1969. Based on advance reports from manufacturers, the outlook was for an additional 45 m.g.d. of desalting new starts during 1970.

TABLE R-112
WORLDWIDE DESALTING DEVELOPMENT ARRANGED BY SIZE OF PLANT

Individual Plant Size Range (1,000 g.p.d.)	No. Plants in Range	Total Capacity in Range (m.g.d.)
25 - 99.9	367	19
100 - 299.9	232	39
300 - 999.9	69	36
1,000 - 4,999.9	51	108
5,000 - or greater	7	69
Total	726	271

About 98% of the total plant capacity is of the distillation process; the remaining 2% is of the membrane and crystallization process types. Approximately 50% of the total world desalting capacity is for the purpose of meeting muncipal water needs An estimated 2% of the total is developed to satisfy special domestic, military, and tourist demands; the remaining 48% is for the industrial use. Worldwide projections made on the basis of the historical desalting plant capacities indicate that the total desalting plant capacity in operation or under construction by the end of 1975 will reach about a billion gallons per day.

PROJECTED USES

Base-loaded Water Supply

In some areas of the world, there is sufficient water storage capacity so that all usuable runoff is collected, stored, and allocated

for beneficial use. This is true of the Colorado River in the United States, and the Jordan River in the Middle East. In other areas, the location of natural resources has caused an influx of population, for development of those resources, into areas that have little or no natural potable water. Examples of these are the oil fields along the Red Sea and the Persian Gulf and the tourist meccas in the Bahamas. The lowest cost desalted water to augment such regions would be from base-loaded desalting plants, operating at full load as much of the time as physically possible.

Operation in Conjunction with Conventional Supplies

Some regions, which have adequate rainfall and water storage during normal years, may face severe restrictions during dry years. Desalting plants require a reliable saline water supply but are not affected by the variations in the natural freshwater supply. If desalting plants could fill the gaps in the natural water supply, a small amount of relatively costly desalted water produced in dry years would firm up a much larger amount of low cost natural water in average or wet years. This type of system requiring close coordination of desalting plants with nnatural supply has been termed "conjunctive use" of desalting. The Office of Saline Water has developed a computer program which is an analytical tool used to help assess alternatives for conjunctive operation of desalting plants. This program selects the proper desalting plant size and the most economical rule for turning the desalting plant on and off to meet a given demand.

A conjunctive distillation plant associated with a power plant would ordinarily have a low pressure turbine to accept steam when the desalting plant is shut down. This low pressure turbine could be used as spinning reserve and/or for peak power by diverting steam from the distillation plant to the low pressure turbine.

Water Quality Control

Most users return water to source with its quality impaired to a greater or less degree, depending on use and level of waste water treatment. In addition to the loading of organics, inorganic minerals are often returned in the waste stream. In an average cycle of municipal and industrial use, and return to source, about 200-500 p.p.m. of salts are added.

As population and demands of industry on our water supply grow, so also will the degree of salinity of water sources for downstream users. However, two choices are available. First, water may be managed in upstream reservoirs for dilution; and secondly, sources of salinity can be treated. The second choice reduces the overall water requirement. Specifically, industries required to treat their waste water may find it economically desirable to extend the treatment to remove all pollutants, including inorganic salts, and recycle water.

The treatment of severe water quality problems posed by acid mine drainage could be examined in the light of the ability of desalting hardware to use such water as feed for conversion to a product suitable for municipal and industrial use.

Ground-water-dependent communities whose sole economic water supply source is brackish water can upgrade such supplies by use of desalting plants.

Research continues on refinement of technology that will be suitable for waste and brackish water. A modest breakthrough in reverse osmosis could find this process widely applied, particularly to industrial waste streams. Of course, suitable methods of brine disposal, particularly in inland locations, must accompany the application of desalting technology for water quality control and re-use.

COSTS OF DESALTED WATER

Experience with present-day plants and studies of future plants that take advantage of expected technological improvements have been analyzed to obtain expected trends in the cost of desalted water. These costs, based on constant-value 1970 dollars, fixed charge rate of 7% to 10%, and probable energy costs, are shown in Figure R-34 for membrane plants operating with brackish water, and in Figure R-35 for seawater distillation plants.

POTENTIAL USES OF DESALTING IN THE NAR

DESALTING FOR NORTHERN NEW JERSEY AND NEW YORK CITY

The importance of desalting as a potential source of supplemental water supply to the North Atlantic Region was first assessed in 1966 by the Northeast Desalting Team to investigate the "potentialities and possibilities of desalting for Northern New Jersey and New York City." The team was composed of Federal, City and private utility representatives. This study was initiated at the time of a severe drought which had extended over a period of five years and threatened the water supply of the major population centers in the Northeast.

A report by the Ralph M. Parsons Company, prepared for the Northeast Desalting Team, explores the feasibility and economics of desalting plants in providing "drought proofing" for the northern New Jersey and New York City water systems. The report concludes that desalting: (1.) is an economical method for adding a fixed, continuous quantity of potable water to the natural supply, or (2.) may be used at intermittent times when the demand upon the natural supply reduces reserve reservoir capacity below safe limits.

While the major consideration in the Parsons engineering study was the use of large desalting plants, up to 300 m.g.d. capacity, to

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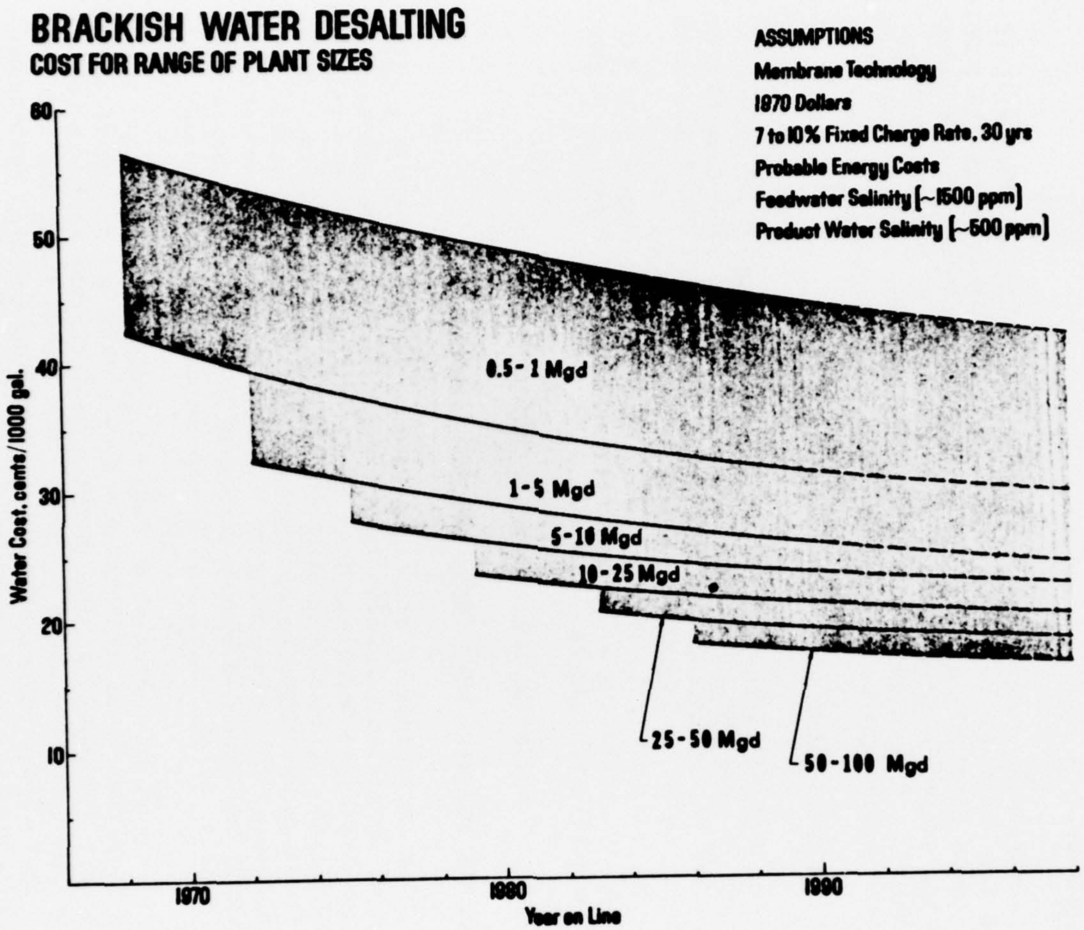

FIGURE R-34. BRACKISH WATER DESALTING - COST FOR RANGE OF PLANT SIZES

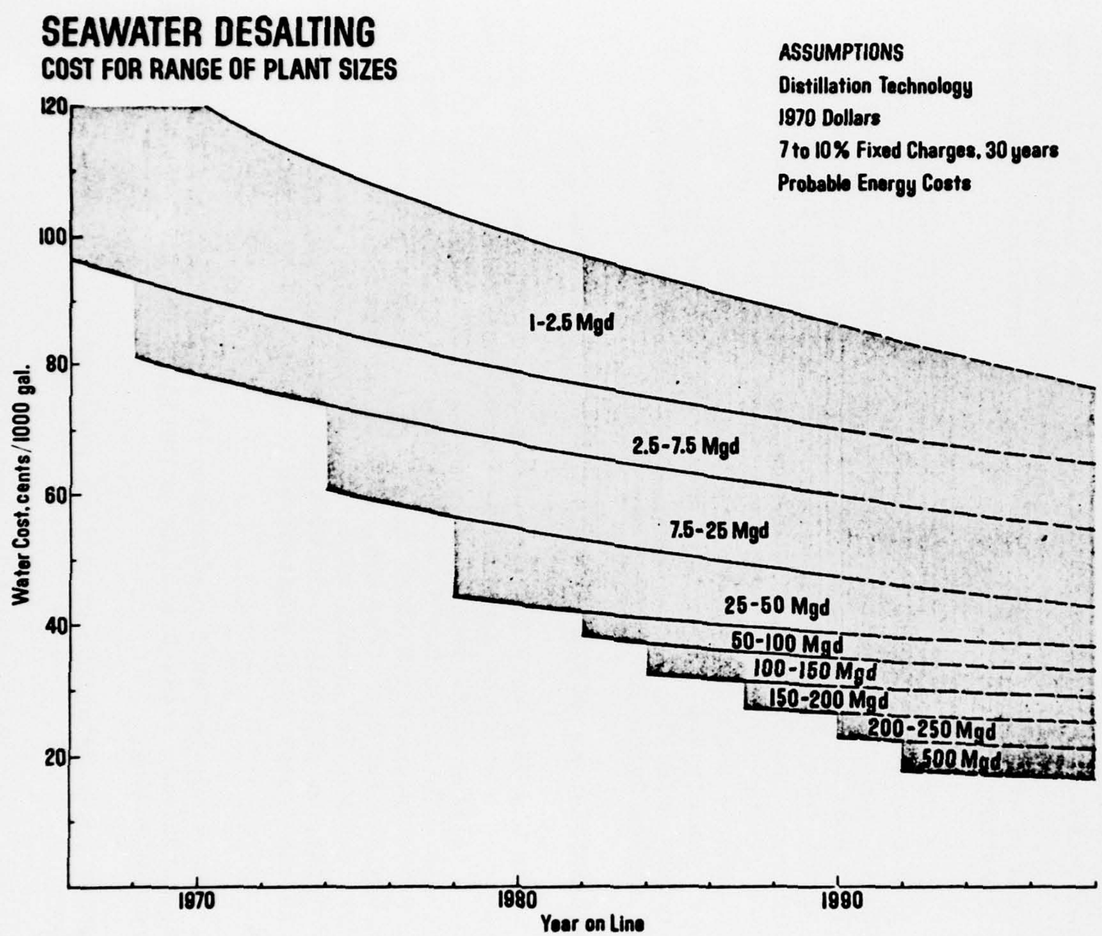

FIGURE R-35. SEAWATER DESALTING - COST FOR RANGE OF PLANT SIZES

provide drought insurance for the New York and Northern New Jersey water systems, the report also discusses employing smaller plants, from 5 to 35 m.g.d., at strategic points in the water systems. These smaller plants might be operated by use of extraction steam from existing power plants.

The lead time for design and construction of these smaller plants would be considerably less than for large plants. Also, the use of small-capacity desalting plants, as an interim measure for supplying or supplementing water supplies, would provide additional time for analysis of the total water problem and for experience with large-scale application of desalination.

As a result of the study by the Northeast Desalting Team, several follow-on studies have been conducted by the Office of Saline Water in cooperation with New Jersey, New York City and New York State. This work was aimed at assessing in greater detail specific aspects of the role of desalting in the Northeast, including the use of smaller scale desalting plants to meet the supplemental and emergency needs of the individual boroughs of New York City, the operation of a skid-mounted desalting plant on polluted feedwaters of the Hackensack River in New Jersey, and the development of data for large-scale membrane desalting plants operating on estuarial feedwaters of the lower Hudson River or the Delaware River.

SEAWATER DESALTING AS EMERGENCY WATER SUPPLY FOR NEW YORK CITY

The New York City Board of Water Supply and the Office of Saline Water supported a study by the Parsons-Jurden Corporation of 5, 10 and 25 m.g.d. desalting units located at several alternative sites in the five boroughs. Up to 125 m.g.d. of capacity was considered at any given site. The multistage flash (MSF) distillation process was selected as most appropriate for near term use. Steam supply might be made available from a city incinerator plant, might be purchased from Consolidated Edison Company, or probably would be generated in an integral steam plant. In the latter case, substantial local oil storage would be required.

The study included evaluations of siting, dissipation of plant effluent, satisfying product quality criteria of the City, product conveyance and blending.

DUAL-PURPOSE POWER-DESALTING PLANTS FOR SUPPLEMENTAL NYC METROPOLITAN AREA SUPPLY

OSW, AEC, the State of New York and New York City, joined with Consolidated Edison of New York, Inc., in a study of the feasibility of dual-purpose nuclear desalting plants to serve future power and water needs of large metropolitan areas.

The study assessed the long-term technical and economic feasibility of operating dual-purpose plants, in conjunction with existing and planned systems and sources of power and water supply for New York

City. Particular attention was given to the quality of water produced by desalting and its integration with existing systems. Conjunctive operation of a 125-750 m.g.d. vertical-tube evaporator-multistage flash (VTE-MSF) distillation plant with a nuclear power plant and the surface water supply system was studied. The feasibility of this concept, including an engineering assessment of the facilities, costs, operating procedure and related factors, was initiated. Water quality and environmental requirements, including health standards and other possible applicable regulations affecting the installation of a large dual-purpose desalting plant in the New York City region, have been cited in the study. The plant was assumed to be located at an offshore site in Long Island Sound.

DISTILLATION PILOT PLANT AT A POLLUTED ESTUARIAL SITE

OSW and the State of New Jersey under a joint agreement provided for testing of a portable 40,000 g.p.d. evaporator which was erected at the Marion Street Generating Station of Public Service Electric and Gas Company. The unit was constructed of conventional materials throughout, and operated by the regular power plant operators of PSE&G.

Feed for the distillation plant was obtained from the Hackensack River, a highly polluted source. No unusual taste or smell was reported in the product. Foaming and carryover in the test plant were no different than those encountered in most seawater desalters operating today. After an initial modification of the deaerating system to make the components function properly, no undue corrosion was encountered from ammonia, H_2S, or other gases associated with pollutants. It was concluded that a potable water supply could be produced with certain pre- and post-treatment measures.

LARGE MEMBRANE PLANTS ON TIDAL ESTUARIES

The Stone and Webster Corporation, under contract to the New York State Division of Water Resources, studied the engineering and economic feasibility of electrodialysis plants operating on variable salinity estuarial feedwater of the lower Hudson River. Conceptual designs of 25, 50, 100, and 300 m.g.d. capacity were considered, as were several sites on the Hudson and Delaware Rivers. The study included a determination of the need for pre-treatment of feed from the estuaries considered.

OFFICE OF SALINE WATER-PENNSYLVANIA STUDY

The Office of Saline Water and the Commonwealth of Pennsylvania have signed an agreement to study the potential of desalting processes to treat acid mine drainage and provide supplemental supplies of freshwater for municipal and industrial users. The agreement covers both studies and the undertaking of research and development work related to the application of desalting processes to the treatment of acid mine drainage and other saline waters, including disposal of brine effluent.

Westinghouse is building a 5 m.g.d. flash evaporator system for the State, to convert mine drainage into potable water. The plant is located on a two-acre site outside Wilkes-Barre on the southeast side of the Susquehanna River. Because of the highly corrosive nature of the feed, the plant has titanium tubing.

OSW, cooperating with other Interior agencies, has been conducting desalting studies on acid mine drainage in Pennsylvania since 1965. Tests, using the reverse osmosis process in a 1,400 g.p.d. pilot plant, were conducted near Kittanning, Pa.

CONCLUSIONS - DESALTING IN THE NAR

The studies cited lead to the conclusion that desalted water should be considered among the alternatives available to planners examining long-term needs in the North Atlantic Region both for water quality control and especially as a means of supplementing surface water storage through the conjunctive operation of desalting plants with existing surface water supplies. Operation of dual-purpose plants appears to be advantageous.

An evaluation of desalting should include (1.) projected costs of desalting, which tend to decrease with large capacity plants and advances in technology, vis-a-vis conventional water project costs, which tend to increase as reservoir sites become scarcer; (2.) the opportunity given by desalting to trade off capital costs for operating costs, and (3.) the ability of desalting to create "new" water, free from legal, political and institutional constraints.

CONSTRAINTS IN DESALTING

PROBLEMS IN DUAL POWER-DESALTING PLANTS

As previously discussed, the most logical and economical sources of steam for large desalting plants are large power plants. Such dual-purpose plants lead to savings of about 15%-20% in water costs, but they lead to the constraints that the desalter must be located physically close to the power source and the operations must be closely coordinated.

A dual-purpose plant may be considered as a special kind of thermal power plant. Adding the distillation plant to a thermal electric generating plant does not result in any real or inherent savings in the power generating cycle, as turbine generators are designed to make use of the available energy in the steam. However, if the desalination process shares (proportionately) in the costs of the steam generating cycle, the larger resulting capacity being shared should result in some economies of scale to the benefit of both power and water production.

The thermal power plant to be used in combination power and water plants may be either fossil or nuclear fueled. However, in the studies for future construction of large plants, engineers have concentrated on nuclear-fueled plants.

If it is desired to maximize water output and only design the power portion of the plant as a complement to the water portion, then the ratio between water and power outputs for a nuclear plant would be about 1 m.g.d. water to two megawatts (MW) electric. However, if there is a demand for a larger portion of electric power than would be produced through use of the above ratio, then it is possible to increase the electric portion of the dual-purpose plant until a power-only system is reached in the limit.

Table R-113 lists the major dual-purpose projects that have been studied in the past few years, together with output characteristics.

TABLE R-113
MAJOR DUAL-PURPOSE DESALTING PROJECTS

Location of Study	Distilled Water Output (m.g.d.)	Net Electrical Capacity (MWe)	Ratio Water to Electrical (m.g.d./MWe)
Bolsa Island, MWD Share	150	295	.51
Bolsa Island, Total Project	150	1800	.085
Gulf of California, Mexico	1000	2000	.50
Ashdod, Israel	100	300	.33
New Jersey-New York	300	1500	.20
New York City	750	4000	.20

Careful planning is required for the integration of a dual-purpose plant into water and power systems. Some of the constraints and factors that must be considered in planning are as follows:

- Under a simple combination design, water is produced whenever electric power is produced; however, by addition of an alternative condensing system (as would be used in a conjunctive or emergency supply), power can be generated independently of water production.

- Because of high capital costs of desalination facilities, facilities should be operated at high plant capacity factors in order to achieve lowest possible unit water costs; this means the steam supply has to be reliable.

- The plant has to be located where both power and water can readily be integrated into existing services.

- Adequate storage facilities must be provided to meet daily peak water deliveries, monthly and seasonal variations in water deliveries, and to provide water during emergency shutdowns of the plant.

- The cost of desalted water should be compared with the cost of the next increment of water that would be brought into the area.

FEED AND PRODUCT CHARACTERISTICS

The feed stream for distillation plants is usually normal seawater (approximately 3.5% dissolved solids), preferably free of silt and organic materials. To assure obtaining clear, cool feedwater, intake pipes or diked channels often extend for a considerable distance offshore and have intake structures designed to retard the uptake of marine life and silt. Bar racks and traveling screens are usually installed at the inland end of the intake system to prevent the entry of seaweed and debris into the plant. Chlorine is periodically injected into the intake system to retard the growth of marine organisms. The feed requirements are very similar to those for power plant cooling water.

The feed stream for membrane plants should not generally contain more than 10,000 p.p.m. of dissolved solids; usual application has been with brackish waters with less than 5,000 p.p.m. Calcium carbonate, calcium sulfate, iron, and manganese are scaling offenders in the electrodialysis process and must be accommodated by removal or treatment. Filtering is also generally required. Calcium sulfate, iron, and manganese are offenders in reverse osmosis plants; in addition, feedwater that contains bacteria or other organisms that attack the RO membranes must be filtered through activiated carbon.

Product distilled from good quality feeds is tasteless and odorless, and is readily blended into water supply systems. If the feed is polluted some contaminants may be distilled with the water,

and if present, are readily removed by activated carbon or neutralized by special treatments.

Distilled water will leach the free lime from concrete and cause it to deteriorate. It will also dissolve the protective film from steel piping and cause it to corrode rapidly. The product water from a distillation plant must therefore be passivated before it is handled in either concrete or steel conveyance systems. Calcium carbonate ($CaCO_3$) added to the distillate at the rate of 25 p.p.m. will render the water passive to both concrete and steel. Product from a membranes plant contains some dissolved solids and is therefore not as aggressive toward concrete or metals.

DESALTING PLANT SITING

Desalting plants will generally be located where all of the following conditions coexist: (1.) proximity to saline water resources and to a market, (2.) shortage of runoff, ground water resources, or economical water-storage sites, and (3.) growing water needs.

A large desalting plant producing freshwater from seawater for municipal and industrial uses will necessarily be located where it can serve a large number of people. A plant producing 150 m.g.d. is sufficient to serve a community of approximately 1 million inhabitants, based on the present per capita requirements in the United States, which are increasing annually.

Dual-Purpose Plants

The suitability of particular sites for dual-purpose power desalting plants includes essentially all the characteristics desired for power-only plants with additional requirements being imposed by the production and distribution of desalted water.

Common to all plants is the requirement for adequate land area for the plant, switchyard, cooling facilities, and for plant expansion where planned. The desalting plant requires only a small fraction of the land area reserved for the power system. A 3000 megawatt power plant requires 1,200-1,600 acres if coal-fired, 200-400 if oil-fired or 300-500 if nuclear. This site must have proper geology, hydrology, and meteorology.

There are some unavoidable conflicts in desirable site characteristics for locating both power plants and dual-purpose plants. For example, under the present licensing regulations, nuclear plants must be located some distance from densely populated regions while the cost of transporting water and power makes it desirable to locate the desalting plant closer to town. However, the use of engineered safeguards in the future may permit nuclear plants to be built closer to large numbers of people. Development of air pollution controls could

achieve the same result for fossil-fueled power plants. An economic optimization may be needed to choose between possible sites.

In addition to these conflicting considerations, there is the general question of land usage. In general, those characteristics which tend to make a particular site attractive for locating a desalting plant, i.e., protected by sandy beaches, gentle sloping terrain, proximity to population zones, etc., also tend to make the site attractive for commercialization or recreation. Land costs are thus high and competition for sites keen.

Information about the seawater environmental factors should be collected before construction of a large desalting plant; and after the plant is put into operation, there should be observations of the environment for any effects produced by the effluent. Effects on marine environment should be studied.

Water-only Plants

Because of economics, water-only plants will tend to be smaller than dual-purpose plants. Sites for these plants should be more easily found. For example, 2.5 acres should suffice for a 10 m.g.d. plant.

Unless steam is available from a utility, a single-purpose distillation plant would have the siting and esthetic problems associated with a small power plant. This includes fuel storage, heat rejection and air quality protection. Fuel consumed by a 10 m.g.d. plant is about equivalent to a 10-20 MW power plant.

Siting of membrane process plants would be similar to siting of water treatment or sewage treatment plants. Neither combustion gases nor waste heat are generated. On the other hand, a suitable brackish feed must be available and it must be possible to dispose of the concentrated water brine.

EFFLUENT DISPOSAL

The problem of effluent disposal has taken on greater significance in recent years because of the increasing interest in quality of the environment. The Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965, authorizes the States to set water quality standards to be approved by the Secretary of the Interior. These standards will set limits to the effects on temperature, salinity, pH, dissolved oxygen, toxicant concentrations, etc., that the disposal of effluents can cause in the water body. Because water quality standards are currently in a state of transition, it may be difficult to determine what criteria the design specifications for the effluent disposal system should meet. However, information about the regulations now in effect should be available from the State where the plant is to be located.

When a desalting plant is located near the coast, the effluent will most likely to disposed of in the ocean. The general question of effluent disposal from a desalination plant into the ocean or in estuaries has been studied quite extensively by the Dow Chemical Co., under OSW contract. Their efforts were directed primarily at evaporative type plants but can be extrapolated to other types. A very brief and selected summary of their conclusions follows:

The effluent from an evaporative type desalination plant is potentially harmful to fresh and marine water biota, primarily because of the copper concentration (the result of corrosion of heat transfer surface), but also because of the high temperature and low oxygen concentration.

Toxicity of the effluent stream can be reduced to acceptable levels by dilution with the bulk water body. Much dilution is gained from power plant cooling water in a dual-purpose plant. Dow recommends that additional required dilution be accomplished with manifolded jet diffusers in the receiving body of water.

Outfalls to the ocean should be located on the open coast. Locations on estuaries and areas with restricted interchange of water should be avoided. If the plant must be located on an estuary, then special design procedures are necessary.

If the plant is to be located inland, then the solution to the effluent disposal problem may be considerably more difficult than when the plant is near the coast. Each plant would have problems unique to its location. For instance, if waste water is used as feed, it may not be clear whether concentrated brine effluent violates water quality standards that permit the more dilute but saline treated waste water that might be discharged without the desalting process. If the standards do apply, the disposal of the concentrated brine effluent from the desalting plant may present a considerable problem. Two methods of brine disposal have been studied: evaporation to dryness and deep-well injection back into the earth. Both are comparatively expensive, solar evaporation depending strongly on land costs, and deep-well disposal costs have been estimated at 25 cents to 70 cents per 1,000 gallons of brine injected. A number of methods of desalting to dryness are being investigated as additional alternatives for disposal of waste brines.

AESTHETIC ASPECTS OF SITING

Large distillation desalting plants are heavy industrial-type structures. Site requirements and uses are similar to electric power plants. Besides the need for heat rejection and brine disposal, the desalting facility would have certain requirements for storage, security fencing, night lighting, highway access, and transmisstion lines. The desalting plant itself would be comparatively low profile.

The visual impact of dual-purpose plants, including a power generation station, would, of course, be more complex than for a power plant by itself. Fossil fuel electric plants require fuel loading and storage facilities (and ash disposal areas for coal-fired) with their attendant structures and associated transportation facilities. The space requirements for these facilities aggravates the problem of concealment. Nuclear power plants are smaller and have fewer auxiliary structures.

On level seacoast terrain the close-up visual impact of these facilities could be mitigated by extensive peripheral site grading and landscaping for screening. Figure R-36 shows the massive character, but relatively clean lines of the Bolsa Island plant (1800 MWe, 150 m.g.d.) which had been proposed for construction in Southern California.

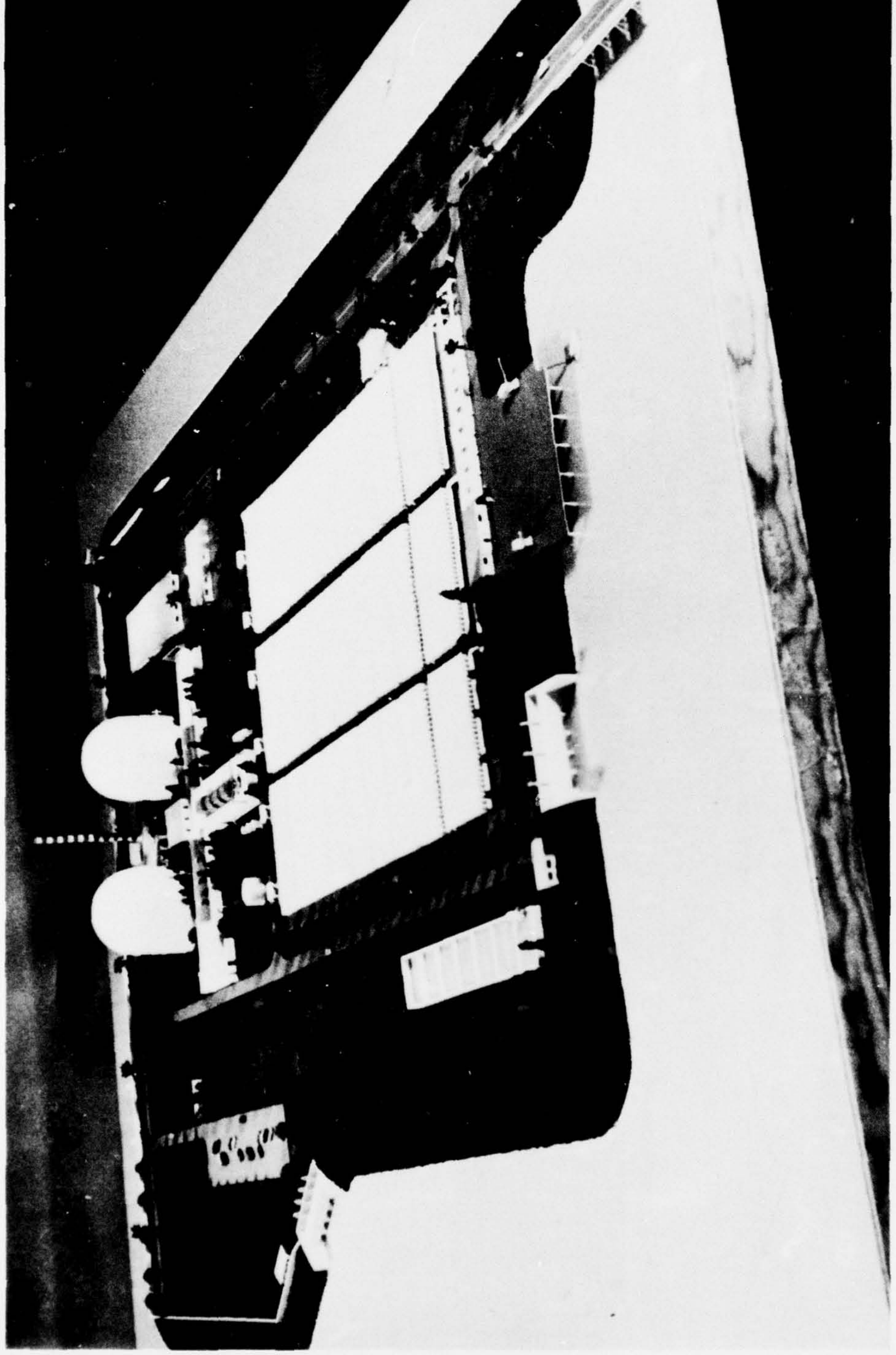

FIGURE R-36. MODEL OF PROPOSED BOLSA ISLAND DUAL-PURPOSE PLANT